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TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 16: Impacts – Ecosystem Services

TOTAL E&P PNG LIMITED

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16.1 Defining the Scope and Information Needs for Ecosystem Services

16. Impacts: Ecosystem Services

16.1 Context and Approach

Ecosystem services represent the intersection of the natural and human environment, and play a vital role in individual and community wellbeing. Accordingly, this chapter draws on relevant baseline information presented in Chapters 7 to 10, and analysis of environmental and social impacts presented in Chapters 11 to 15.

The International Finance Corporation (IFC) defines ecosystem services, as the benefits that people, including businesses, derive from ecosystems, and has divided these services into four categories (IFC, 2019):

- Provisioning services – the goods or products obtained from ecosystems, such as food, timber, fibers, fresh water and medicinal plants.
- Cultural services – the non-material contribution of ecosystems to human wellbeing, such as recreation, spiritual values and aesthetic enjoyment.
- Regulating and maintaining services – the contributions to human wellbeing arising from an ecosystem's control of natural processes, such as climate regulation, disease control, erosion prevention, water flow regulation, surface water purification, carbon storage and sequestration, and protection from natural hazards.
- Supporting services – the natural processes, such as soil formation, nutrient cycling and primary production, that maintain the other services.

Figure 16.1 illustrates the different types of ecosystem services in each category, and Table 16.1 highlights the requirements in each IFC performance standard, as they relate to addressing ecosystem services (IFC, 2012).

Table 16.1 – Ecosystem Service Requirements in the IFC Performance Standards

IFC Performance Standard	Summary of Requirements
1: Assessment and Management of Environmental and Social Risks and Impacts	Requires all reasonably expected risks and impacts related to ecosystem services to be identified. Requires that the PAOI is broad enough to include indirect impacts on ecosystem services.
4: Community Health, Safety and Security	Requires any impacts on health and safety due to direct impacts on priority ecosystem services to be assessed. For example, the loss of natural buffer areas, such as mangroves that mitigate natural hazards such as flooding, may cause increased vulnerability and community-safety–related risks and impacts.
5: Land Acquisition and Involuntary Resettlement	Loss of access to provisioning ecosystem services needs to be considered when developing a livelihood development plan, particularly when assessing the suitability of replacement land and/or access to natural resources for resettlers.
6: Biodiversity Conservation and Sustainable Management of Living Natural Resources	Requires a systematic review of all ecosystem services a project will impact or depends on to identify priority ecosystem services. The client must demonstrate how they have avoided, minimized and mitigated impacts on priority ecosystem services.
7: Indigenous Peoples	Priority provisioning and cultural ecosystem services need to be assessed and understood in an Indigenous Peoples Plan, as they are likely to be central to the identity and/or cultural, ceremonial or spiritual aspects of Indigenous Peoples' lives.
8: Cultural Heritage	In restoring cultural heritage either in situ or in a new location, any ecosystem processes needed to support that cultural heritage need to be maintained or restored.

TYPES OF ECOSYSTEM SERVICES AND THEIR CATEGORIES

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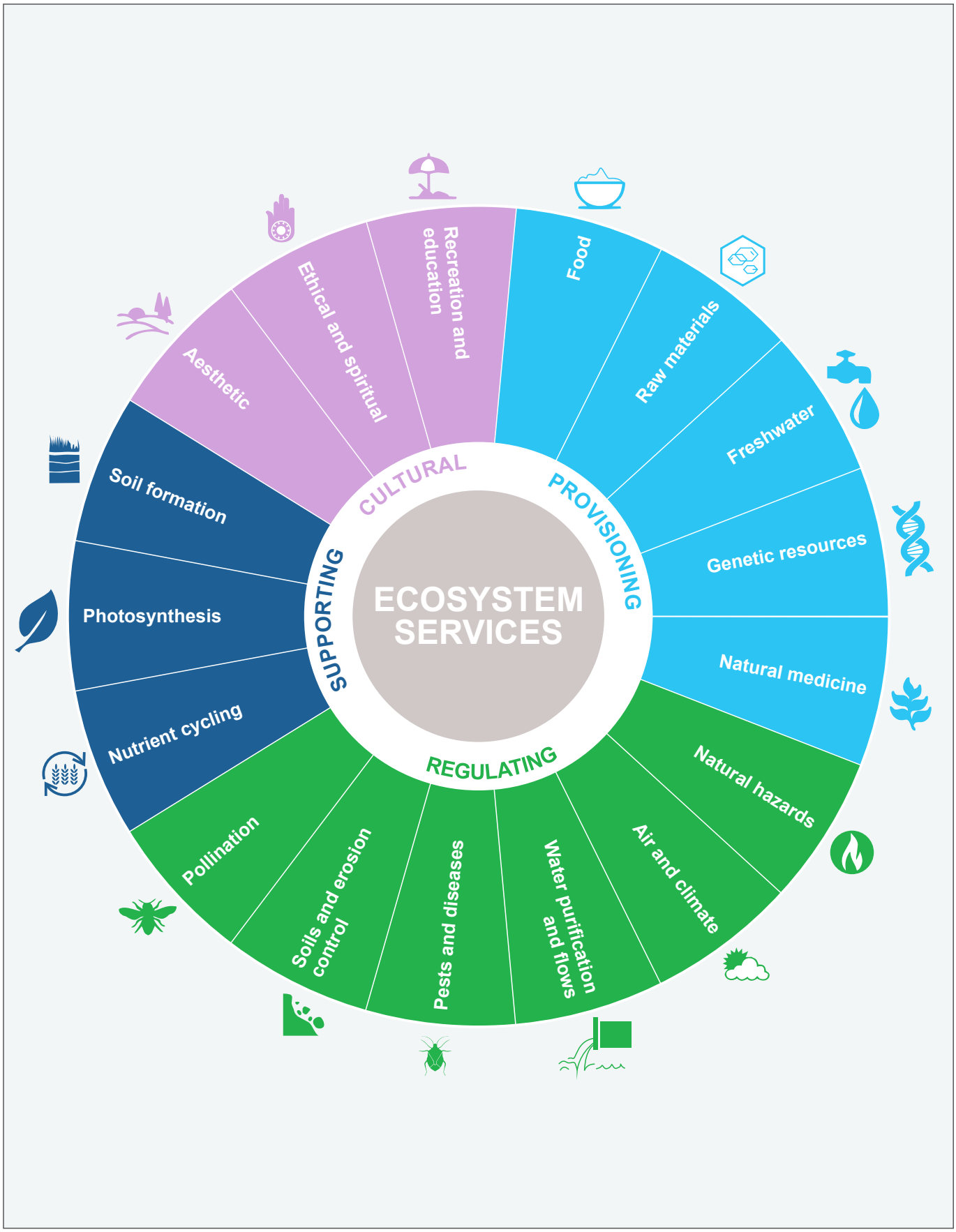
FIGURE 16.1



Adapted from WWF (2016).

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ECOSYSTEM SERVICES IDENTIFICATION, PRIORITIZATION AND IMPACT ASSESSMENT APPROACH

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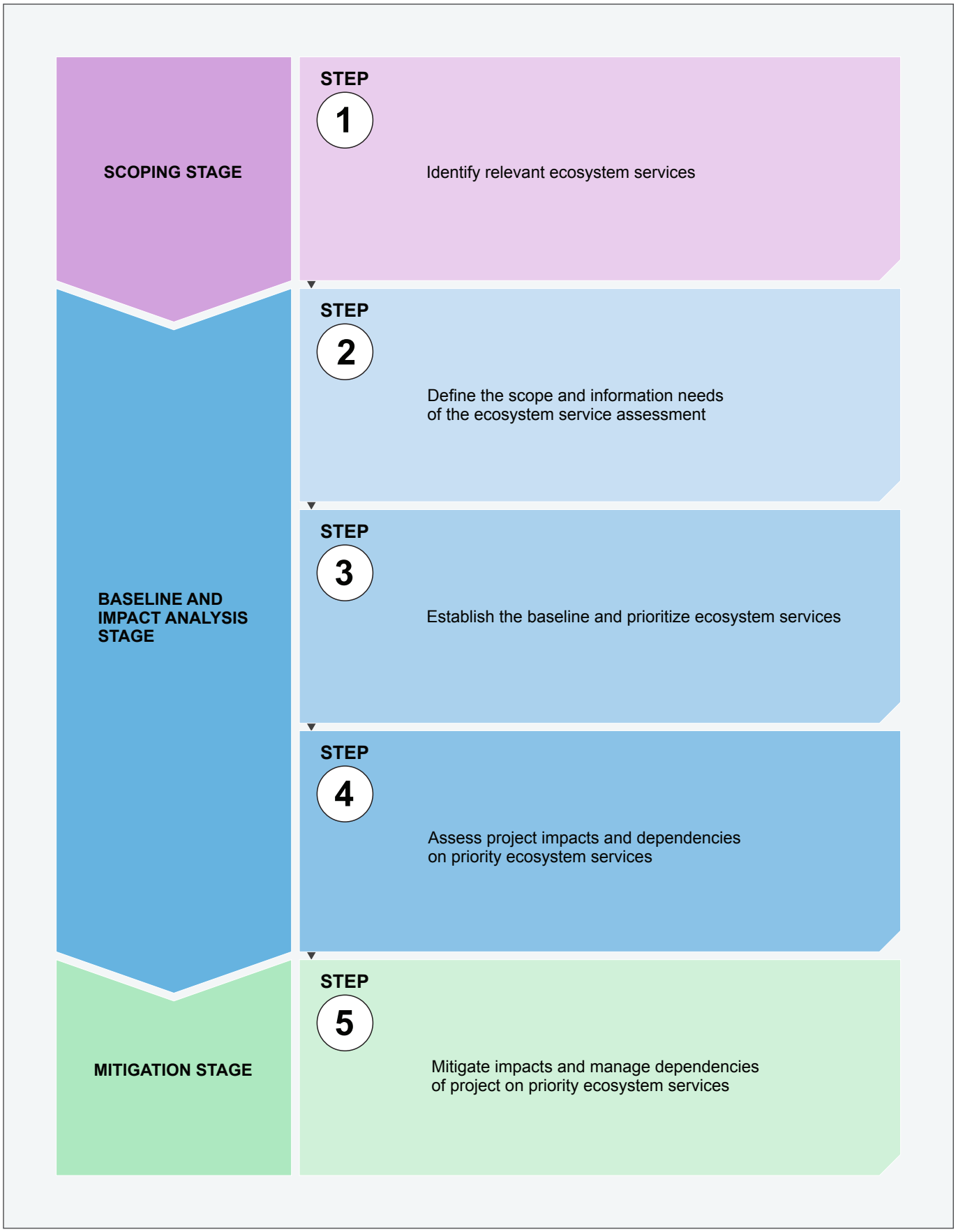
FIGURE 16.2



Adapted from WRI (2013).

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16.2 Discipline-specific Assessment Method

The ecosystem services identification, prioritization and impact assessment approach (see Figure 16.2) used in this chapter is based on the method outlined in the World Resources Institute's (WRI's) Weaving Ecosystem Services into Impact Assessment (WRI, 2013) and on Guidance Note 6 (IFC, 2019).

Section 16.3 describes how relevant ecosystem services were identified and provides a preliminary list of ecosystem services.

An integrated approach was used to collect the information required for the ecosystem services assessment. Information relevant to ecosystem services and movements of communities was collected through consultation with communities in the Project area of influence (PAOI) during the social baseline surveys and ecosystem services interviews (reported in Part 18 of Volume 2). These activities specifically sought beneficiaries' views on the uses of resources from the natural environment and their perceptions of the importance of those resources. Attachment 16.1 describes how this information was captured. Full details on survey methods is provided in Part 23 of Volume 2.

Section 16.4 establishes the baseline for ecosystem services identified as relevant to the Project and prioritizes them based on an assessment of the value of each service, as determined by the importance of the service to ecosystem beneficiaries and the replaceability of the service.

Section 16.5 identifies potential impacts on priority ecosystem services from Project activities, and Section 16.7 assesses these impacts after mitigation measures are applied.

The significance assessment approach described in Chapter 3 was used to characterize the impacts relevant to provisioning ecosystem services. The assessment of residual impacts, assuming the effective implementation of (i) avoidance, mitigation and management measures for adverse impacts and (ii) measures to optimize opportunities, is conducted by examining both the magnitude of the impact (Table 16.2) and the sensitivity of the people, communities and natural resources being impacted (Table 16.3). This interaction between magnitude and sensitivity is expressed in a matrix form (Table 16.4).

Cultural, regulating, maintaining and supporting services are identified but are not assessed in this chapter as they are considered and assessed in Chapters 11, 14, 15 and 17.

Table 16.2 – Ecosystem Services Impact Assessment Magnitude Criteria

Rating	Description
Very High	♦ Irreversible and significant change compared to baseline conditions. ♦ The impact causes the loss of all or a significant proportion of the availability or functionality of an ecosystem service and/or has implications for people outside of the PAOI. ♦ The impact causes commercial industries to shut-down. ♦ The long-term viability of the service is threatened. ♦ Communities are unable to source an alternative or replacement service.
High	♦ Noticeable medium-term (i.e., more than 10 years) change compared to baseline conditions. ♦ The impact causes a high reduction in the availability or functionality of the ecosystem service and/or has implications for more than 50% of the people in the PAOI. ♦ The impact causes commercial industries to partially shut-down. ♦ The impact does not threaten the long-term viability of the service. ♦ Significant increase in community time or effort is needed to source an alternative or replacement service.

Table 16.2 – Ecosystem Services Impact Assessment Magnitude Criteria (cont'd)

Rating	Description
Medium	♦ Noticeable short-term (i.e., 5 to 10 years) change compared to baseline conditions. ♦ The impact causes a medium reduction in the availability or functionality of the ecosystem service and/or has implications for 25 to 50% of the people in the PAOI. ♦ The impact causes commercial industries to be temporarily disrupted and/or to incur additional costs. ♦ Some increase in community time or effort is needed to source an alternative or replacement service.
Low	♦ Limited change compared with baseline conditions, lasting less than 5 years. ♦ The impact is localized and causes a small reduction in the availability or functionality of the ecosystem service and/or has implications for a less than 25% of the people in the PAOI. ♦ The impact causes commercial industries to be temporarily disrupted and/or to incur additional costs. ♦ Limited or no increase in community time or effort is needed to source an alternative or replacement service, or the service is highly replaceable.
Negligible	♦ No appreciable impact compared with baseline conditions. ♦ No appreciable impact commercial industry operations. ♦ The impact is within a normal range of variation.
Positive	♦ Improvement compared to baseline conditions. ♦ The impact improves the availability or functionality of the ecosystem service and/or has positive implications for people in the PAOI.

Table 16.3 – Provisioning Ecosystem Services Impact Assessment Sensitivity Criteria

Rating	Description
High	♦ Limited or no capacity to adapt to change. Limited or no capacity to realize opportunities. ♦ Low replaceability: few to no spatial alternatives; alternatives are difficult to access, costly or unsustainable; low acceptance of alternatives by ecosystem beneficiaries. ♦ Community, service or area is unaffected by this impact prior to Project interaction. ♦ Resource or area has high symbolic importance to cultural or traditional value systems. ♦ Resource provides the sole source of food or income for local people, or resource on which they are frequently dependent. ♦ Many communities depend on the resource or service and have no or limited capacity to access nearby alternatives. ♦ Resource is nationally important to commercial beneficiaries or the Project itself. ♦ Community has no capacity to access nearby alternatives to the affected resource or service. ♦ Resource cannot be relocated or replaced without major loss of cultural values. ♦ Site is protected by local, national and international laws or treaties.
Medium	♦ Some resilience to change. Some capacity to realize opportunities. ♦ Moderate replaceability: some spatial alternatives; alternatives are moderately accessible, affordable or sustainable; moderate acceptance of alternatives by ecosystem beneficiaries. ♦ Some sign of exposure to this impact is already evident in the community, service or area prior to Project interaction. ♦ Resource or area has moderate symbolic importance to cultural or traditional value systems. ♦ Resource is one upon which local people occasionally depend for provision of food or income. ♦ Resource is locally important to commercial beneficiaries or the Project itself. ♦ Community has some capacity to access nearby alternatives to the affected resource or service. ♦ Resource can be relocated or replaced but with some loss of cultural values. ♦ Site is not specifically protected under local, national or international laws or treaties.

Table 16.3 – Ecosystem Services Impact Assessment Sensitivity Criteria (cont'd)

Rating	Description
Low	♦ Easily adaptable to change (or no change required). High capacity to realize opportunities. ♦ High replaceability: many spatial alternatives; alternatives are accessible, affordable or sustainable; high acceptance of alternatives by ecosystem beneficiaries. ♦ Community, service or area is already affected by this impact, prior to Project interaction. ♦ Resource or area has minimal symbolic importance to cultural or traditional value systems. ♦ Resource is one upon which local people rarely depend for provision of food or income. ♦ Resource is not important to commercial beneficiaries or the Project itself. ♦ Community has a high capacity to access nearby alternatives to the affected resource or service. ♦ Resource can be relocated or replaced or is a type common in the surrounding region. ♦ Site is not specifically protected under local, national or international laws or treaties.

Table 16.4 – Ecosystem Services Significance of Assessment Matrix

Magnitude of Impact	Sensitivity of Value		
	High	Medium	Low
Very High	Severe	Major	Moderate
High	Major	Moderate	Moderate
Medium	Moderate	Moderate	Minor
Low	Minor	Minor	Minor
Negligible	Negligible	Negligible	Negligible
Positive	Positive	Positive	Positive

16.3 Identifying Relevant Ecosystem Services

Relevant ecosystem services on which the Project may impact were identified by analyzing the ecosystems and ecosystem services that Project activities could impact either directly or indirectly, and the ecosystem beneficiaries that could be positively or negatively affected due to these impacts.

The different ecosystems relevant to the Project areas were identified through baseline studies, and the results are discussed in Chapter 7. Broad vegetation groups were used to categorize ecosystems into habitat and land-use types that will potentially be impacted by the Project (Table 16.5).

Table 16.5 – Habitats and Land Uses Relevant to Ecosystem Services

Habitat/Land Use	Description
Forest	Includes hill forest, alluvial forest, swamp forest, littoral forest and riverine habitat.
Wild stands of sago woodland	Woodlands dominated by sago (Swamp woodland (Wsw)) rather than where sago is a component of other vegetation types.
Rivers and waterbodies	Includes the estuarine zone, rivers, lakes, wetlands and other, generally freshwater, waterbodies in the study area.
Mangrove	Includes fringing mangroves, main mangrove associations, nipa palm and transitional mangrove forest.
Nearshore	Refers to the waters from the top of the high-water mark to the 15-m depth contour. The habitat includes coral reefs and seagrass beds, beaches and intertidal habitats (e.g., mudflats).
Offshore	Refers to marine waters that are seaward of the nearshore environment and generally encompasses deeper waters beyond the 15-m depth contour.

Table 16.5 – Habitats and Land Uses Relevant to Ecosystem Services (cont'd)

Habitat/Land Use	Description
Subsistence land use and villages	Cropping and plantations, temporary gardens, dwellings and community infrastructure.

Ecosystem services relevant to each of these ecosystems were identified based on a review of ecosystem services guidance documents (e.g., Landsberg et al., 2011; WRI, 2013; IPIECA and IOGP, 2011), previous ecosystem services impact assessments, and the experience of the environmental and social technical practitioners on the study team.

Individuals and communities were identified as the primary ecosystem beneficiaries in the PAOI. A list of communities in the PAOI is provided in Section 9.5.1. Extensive consultation with these primary ecosystem beneficiaries, through formal and informal surveys, interviews and focus group discussions, was undertaken during the data collection process (Attachment 16.1). Commercial ecosystem beneficiaries include companies involved in logging and commercial fishing operations.

Project activities and drivers of change, or activities likely to cause impacts, were also considered to identify which ecosystem services were most relevant to the Project and whether the Project had direct management control or influence over them.

Ecosystem services that were screened out by applying these filters were excluded from further investigation. Those that were considered relevant to the ecosystems, Project activities and beneficiaries form the preliminary list of ecosystem services, (Table 16.6).

Table 16.6 – Preliminary List of Ecosystem Services

Provisioning Services	Regulating and Maintaining Services
♦ Wild food (bushmeat). ♦ Wild food (plants, nuts and fruit). ♦ Wild food (freshwater and marine species). ♦ Food (crops). ♦ Food (livestock). ♦ Fuel (firewood). ♦ Traditional medicine. ♦ Timber and other wood products. ♦ Non-timber forest products (fibers, resins). ♦ Fresh water (domestic use). ♦ Rivers (transportation). ♦ Marine transportation. ♦ Commercial marine fisheries. ♦ Timber and logging concessions.	♦ Control of erosion and sedimentation. ♦ Regulation of surface and groundwater (including flows). ♦ Regulation of natural hazards. ♦ Regulation of air quality. ♦ Regulation of climate. ♦ Water purification and waste treatment. ♦ Regulation of soil quality. ♦ Regulation of diseases. ♦ Regulation of pests. ♦ Pollination and seed dispersal. ♦ Seed bank for natural regeneration.
Cultural Services	**Supporting Services**
♦ Cultural sites. ♦ Traditional practices.	♦ Provision of habitat for plant and animal species. ♦ Nutrient cycling. ♦ Primary production. ♦ Water cycling. ♦ Soil formation. ♦ Genetic resources.

16.4 Baseline Characterization and Prioritization of Ecosystem Services

16.4.1 Prioritization Method

The importance of ecosystem services to beneficiaries has been assessed according to the following criteria adapted from ERM (2013):

- Intensity or frequency of use, e.g., daily, weekly, seasonal, occasional.
- Scope of use, e.g., households, villages, commercial.
- Degree of dependence, e.g., contribution to diet, income or employment.
- Importance expressed by ecosystem beneficiaries.

Not all these criteria are relevant to each ecosystem service; but when they are relevant, they are considered in combination to determine the importance of the ecosystem service, e.g.:

- Low importance: Occasional use (intensity) by some households (scope). No or minimal contribution to diet, income or employment (dependence) and is not considered valuable by ecosystem beneficiaries (importance).
- Moderate importance: Regular (weekly) use by some or most households. Contributes to diet, income or employment and is considered to be of some value by ecosystem beneficiaries.
- High Importance: Frequent (daily) use by most households. Significant contribution to diet, income or employment and is considered valuable by ecosystem beneficiaries.

Replaceability of ecosystem services is assessed according to the following criteria adapted from ERM (2013):

- The existence of spatial alternatives, i.e., alternatives are available in other locations or alternatives are otherwise accessible, including both natural and artificial substitutes.
- The accessibility, cost and sustainability of potential alternatives.
- Preference or cultural appropriateness of alternative services.

Again, not all criteria are relevant to each ecosystem service; but when they are relevant, they are considered in combination to determine the overall replaceability of the service, e.g.:

- Low replaceability: Few to no spatial alternatives; alternatives are difficult to access, costly or unsustainable; low acceptance of alternatives by ecosystem beneficiaries.
- Moderate replaceability: Some spatial alternatives; alternatives are moderately accessible, affordable or sustainable; moderate acceptance of alternative by ecosystem beneficiaries.
- High replaceability: Many spatial alternatives; alternatives are accessible, affordable or sustainable; high acceptance of alternatives by ecosystem beneficiaries.

The importance and replaceability of ecosystem services are used to place a value rating on each ecosystem service (Table 16.7). The value ratings for importance and replaceability are based on interpretations of field data, discussions with ecosystem beneficiaries and field observations. The value ratings also reflect beneficiaries' interpretations of the rating criteria and may reflect some biases.

This value rating is used to prioritize the provisioning and cultural ecosystem services that are later assessed in the impact assessment. Those scoring a high or very high rating in the

prioritization exercise are considered priority ecosystem services for the impact assessment. Some services rated as medium are also discussed in the impact assessment by exception (and marked with an asterisk (*) in Table 16.9), where they are of high importance to beneficiaries.

Table 16.7 – Value Rating Matrix for Ecosystem Services

Importance of Service to Ecosystem Beneficiaries	Replaceability of Service		
	High	**Moderate**	**Low**
Low	Low	Low	Medium
Moderate	Low	Medium	High
High	Medium	High	Very High

Source: Matrix adopted from ERM (2013).

Professional judgment was used to determine the value rating for regulating, maintaining and supporting services (Table 16.9), based on the data gathered through baseline studies.

16.4.2 Baseline Characterization

Ecosystem services are characterized through a summary of the baseline conditions of the preliminary ecosystem services listed in Table 16.6, incorporating their relevant habitats or land uses in the PAOI, their importance to local communities (where relevant), their replaceability and their assigned value rating as described in Section 16.4.1. A more detailed description of baseline conditions and the data supporting statements in Tables 16.8 and 16.9 can be found in Chapters 7, 8 and 9, and Parts 13 and 18 of Volume 2.

The baseline characterization also takes into consideration external factors (i.e., not Project-related) that may affect current and future service provision such as population growth, economic and land use changes and climate change, and recognizes that regulating, maintaining and supporting services influence cultural and provisioning services. For example, fisheries productivity depends upon regulating and supporting services such as erosion control, and the regulation of pests and diseases, climate and water quality. Benefits to communities and commercial fisheries through provisioning services are derived from these supporting ecosystem services.

Villages have been categorized as either coastal or inland, as a basic way of separating them by ecological system to provide a baseline for the ecosystem services (Attachment 16.1). Some variance exists between villages in each category, e.g., the villages of Aumu and Wabo are both categorized as inland, yet they exist in different ecological zones, some 90 km apart. The communities have been combined under a single value rating when the importance and replaceability ratings are the same for both inland and coastal communities.

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Wild food (bushmeat)	Forest	Forests throughout the PAOI provide a range of animals that are eaten and/or sold for income. Inland communities typically have a higher dependence on bushmeat for protein than coastal communities, who have access to marine resources. While game items, such as wild pigs and cassowaries, are highly prized and are actively pursued, most procurement activity is highly opportunistic; and most of the hunting returns comprise many kinds of smaller food items. Many households earn some revenue from occasional sales of hunted or collected animal foods, and a few earn significant annual revenue from the sale of bushmeat.	Inland	High	High	Medium*
			Coastal	Moderate	Moderate	Medium
	Subsistence land use and villages	Bushmeat hunted, collected and consumed from gardens commonly includes: ♦ Small vertebrate (non-volant mammals, birds, reptiles, frogs). ♦ Flying foxes.	Inland/Coastal	Moderate	High	Low
Wild food (plants, nuts and fruits)	Forest	Forests in the PAOI provide at least 46 plant species that are used as a supplementary food to sago and garden food crops. Trees and palms have the most uses, providing edible nuts, fruits and leaves. Various, relatively common, trees are important for fruit or nut production. These trees are widespread across hill forest, alluvial forest and, to a lesser extent, swamp forest.	Inland	High	High	Medium
			Coastal	High	Moderate	High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Wild food (plants, nuts and fruits) (cont'd)	Mangroves	Nipa palms that produce abundant edible starchy nuts each year dominate much of the mangroves of the delta. These are seasonally available for the communities in the Mangrove ecological zone and are an important dietary component of people from villages from the Maipua, Koriki, Iare and Kaimare language groups. Mangrove forests do not occur inland of the Purari River tidal limits and are of lesser importance to inland people as a seasonal food source.	Inland	Low	Moderate	Low
			Coastal	High	High	Medium
	Wild sago stands	Sago is the primary staple food in the PAOI, and wild sago is an important famine food. Wild sago stands cover approximately 25,351 ha (9%) of the PAOI. An additional 13,890 ha also contain sago but as a secondary vegetation component (see Figure 9.10). Sago harvested from wild sago stands is less preferred than planted sago, as it is harder to access and has an unfavorable texture and flavor, and many spatial alternatives are accessible for both inland and coastal villages.	Inland/Coastal	High	High	Medium*
Wild food (aquatic species)	Rivers (including estuaries and waterbodies	A range of animal resources are hunted or collected along the larger rivers and channels of the Purari River and delta distributaries. Most of the species caught by local communities are widely available. Fishing is considered an essential subsistence activity and the selling of surplus catch to markets and logging camps is opportunistic; however, commercial-scale activity has reportedly declined as villagers have sought other sources of income.	Inland	Moderate	High	Low
			Coastal	High	High	Medium*

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Wild food (aquatic species) (cont'd)	Nearshore	Artisanal fishing is an important provisioning service and is a primary source of village income for several coastal communities in the PAOI. Artisanal fisheries are almost exclusively within the 3 nautical mile coastal zone. Prawn fishing is most commonly undertaken with hand-operated nets in wadable depths during the seasonal prawn migration out of the Purari delta into the coastal zone. Collecting crabs and shellfish is a very regular activity among members of the river and coastal villages. For the two weeks prior to the household survey, 36 to 76% of households devoted effort to collecting aquatic resources.	Inland	Low	High	Low
			Coastal	High	High	Medium*
Food (crops)	Subsistence land use and villages	Agriculture is dominated by a type of subsistence agriculture known as shifting cultivation where staple food crops are grown in temporary 'gardens', which are made by clearing and burning tall woody regrowth, typically over 15 years old. All communities make small household gardens on hill sides, along the banks of the Purari River and other waterways, in logged-over alluvial forest and occasionally in small cleared patches of nipa palms in the mangroves where crops are planted on raised mounds. Larger cultivated areas are more prevalent inland from Orokolo Bay in swamp woodland areas. Crop cultivation is very important for the coastal and inland Orokolo villages where there is greater access to more fertile alluvial plains. Coconut is planted in coastal and inland Orokolo village gardens and is an important famine food.	Inland	Moderate	High	Low
			Coastal	High	Moderate	High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Food (crops) (cont'd)	Subsistence land use and villages	Sago is the main staple food for all the villages and an important famine food, as it is resilient to flood and drought. Planting and harvesting sago are the most important food production activities across the PAOI.				
Food (livestock)	Subsistence land use and villages	Domestic livestock in the PAOI includes pigs and chickens. Pigs are valued commodities and are reared for both meat and bride price or compensation payments. Pig ownership rates vary across the PAOI. Most households in the PAOI keep chickens. Both the eggs and the birds are regularly eaten. Chickens are a moderate source of protein.	Inland/Coastal	Moderate	Moderate	Medium
Fuel (firewood)	Forest	Firewood is the main resource for cooking food in the PAOI. Almost any tree species can be used, provided it is dry; however, several species are preferred. Firewood is collected from as close to the village as possible to minimize carrying the wood.	Inland/Coastal	High	Moderate	High
	Nearshore	Community members from Kaivukavu (coastal Orokolo) collected nearly all their firewood (as driftwood) from the beach; however, firewood collection along the beach is subject to clan ownership restrictions, and frequent disputes arise over ownership of beach firewood in the coastal Orokolo villages.	Coastal	High	Moderate	High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Traditional medicine	Forest	Fifty-eight medicinal plant species were identified in the PAOI, including: ♦ *Myristica* sp. – Fruit of the tree are eaten to cure cough. ♦ *Ficus polyantha* – Sap from the tree is mixed with water and drunk to cure diarrhea. ♦ *Laportea decumana* – Leaves of the shrub are rubbed on skin as a pain killer. Most are relatively common and are collected in forested areas near villages. A full list of medicinal plants can be found in Part 18 of Volume 2.	Inland/Coastal	High	High	Medium
Timber and wood products	Forest	Timber is most commonly used in the PAOI for building materials, particularly house posts and canoes. Many different tree species are available that can be used for house construction, particularly in hill forest; but different species are used for different house components. Preferred tree species are found in natural stands, can be scattered and take a long time to replace or regrow.	Inland/Coastal	High	Moderate	High
	Mangrove	Mangrove cedar (*Xylocarpus granatum*) and blind-your-eye mangrove (*Excoecaria agallocha*) are used for house posts, but these are not the preferred house post species.	Inland/Coastal	Moderate	High	Low
Fibers and resins	Forest	The most widely used plants for domestic purposes are bamboo, palms, rattan and the tree species *Trichospermum*.	Inland/Coastal	High	High	Medium
	Sago and Mangrove	Seventy-three percent of houses in the PAOI are made of traditional materials, i.e., roof made of sago leaves, nipa palm leaves or grass. Many different spatial alternatives are available for sago and nipa palms across the PAOI.	Inland/Coastal	High	High	Medium

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Fresh water (domestic use)	Rivers and waterbodies	Sixteen percent of households in the PAOI rely on a river or creek as their main source of drinking water. People residing in Ura, Wabo, Subu, Subu 2, Poroi 2, Poroi 3, Upaia, Aiere, Kairu'u, Akoma, Evara, Kaevaria, Kairimai, Aivai, Apiope and Mapaio Fish Camp extract water from the Purari River or its tributaries for drinking. Other communities use rainwater, tanks or shallow groundwater wells as their main source of drinking water but may rely on river or creek water during droughts when alternative sources may not be available. Coastal communities obtain fresh water from several sources, including shallow wells, tanks and rivers. They rely less on rivers and lagoon sources than inland communities do. Other than river water, tanks (where they exist) or water containers are used to collect rainwater. Groundwater sources are uncommon inland.	Inland/Coastal	High	Moderate	High
	Subsistence land use and villages (groundwater)	Orokolo villagers use groundwater for drinking and washing. The groundwater is obtained from shallow wells and provides reliable year-round water. The microbial water quality in sampled groundwater wells in these villages is poor, as they have high coliform counts. This could be due to domestic animals and wildlife having open access to wells and springs; and the latter are, in some cases, close to latrines. There are few alternatives to groundwater in coastal areas, even with rainwater tank installation, as the tanks are quickly depleted and do not provide year-round water security.	Coastal	High	Low	Very High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Rivers (transportation)	Rivers and waterbodies	The main mode of transport in the PAOI is on rivers using dugout canoes, motorized dugout canoes or dinghies. The PAOI has no roads other than disused logging tracks; consequently, no motor vehicles or motorbikes were recorded in the PAOI. Most river traffic generally involves one to four hours' travel from villages to access food gardens, sago processing sites, or hunting and gathering sites; to go fishing or to travel to schools and aid posts. Villages along the rivers relocate every few decades, due to rapid siltation.	Inland/Coastal	High	Moderate	High
Marine (transportation)	Nearshore	People living along the Orokolo Bay coastline regularly transit along the coast to sell marine produce, to access markets, and health and education facilities or to visit relatives. Sea travel forms part of the journey to the regional center of Kerema for all people in the PAOI. Sea travel is expensive and can be dangerous. Walking (usually along the beaches, which provide a kind of 'coastal highway') is the only alternative.	Coastal	High	Moderate	High
Commercial marine fisheries	Nearshore	The Gulf of Papua Prawn Fishery is the principal commercial fishery in the PAOI. Licensed trawlers typically operate offshore of the 3-nautical mile limit, but some operators are granted access to the 2- to 3-nautical mile zone via joint venture agreements with specific local communities that allow profit sharing on the value of the catch. The Gulf of Papua Prawn Fishery is principally an export fishery.	Coastal	Moderate	Moderate	Medium

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Commercial marine fisheries (cont'd)	Nearshore (cont'd)	Coastal villagers interact with the prawn fishery by trading trawl by-catch. Prawn trawling is a frequent activity and significantly contributes to the PNG economy and employment. Prawn fishing grounds extend across the Gulf of Papua; therefore, potential spatial alternatives exist for this fishery. The Torres Strait Tropical Rock Lobster Fishery is the other key commercial fishery. Commercial rock lobster fishing does not occur in the PAOI, but migrating lobsters may cross the offshore export pipeline route.	Commercial beneficiaries	High	Moderate	High
Timber from logging concessions	Forest	Seven logging concessions exist in or adjacent to the Project study area of which only Vailala Block 3 and East Kikori are active. The main active logging concession is Vailala Block 3 Forest Management Area, which extends from the south bank of the Purari River to the coast and operates over 196,353 ha, all of which is in the study area. The other active concession is the East Kikori Timber Rights Purchase area of which only 10,900 ha overlaps the study area. Turama Forest Industries is still to develop the Baimuru Block 3 Forest Management Area, which is west of the Purari River. The study area provides extensive forest resources that are suitable for small-scale logging using portable sawmills; however, small-scale forestry is almost absent from the study area other than at Paevera, where the only known portable sawmill is based.	Inland/Coastal	Moderate	Moderate	Medium
			Commercial beneficiaries	High	Moderate	High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Timber from logging concessions (cont'd)	Forest (cont'd)	In 2016, logging activity contributed to income and employment for some PAOI communities, e.g., Mapaio, Aivai, Upaia and Wabo. Some communities benefit from logging operations; however, survey data indicated general dissatisfaction with these benefits. Currently, there is no known harvesting of the high-value forest products eaglewood and massoy; although, it is possible that these products will be harvested in the future.				
Cultural Services						
Cultural sites	All	Tangible cultural heritage sites in the PAOI are often associated with landscape features, such as hills, caves, river mouths, rocks, individual trees or vegetation stands. Many communities in the PAOI reported spirit sites were of high local importance during consultations. Eight spirit sites were formally recorded in the PAOI during surveys. Many more sites were named during consultations; however, they were not formally recorded because of confidentiality or difficulty in accessing the sites.	Inland/Coastal	High	Low	Very High
Traditional practices	All	Traditional practices, such as hunting, fishing, and making pandanus mats and bilums, rely on natural resources sourced from forests, mangrove, rivers and marine environments. Some examples of resources used for traditional practices are: ♦ Palm (*Actinorhytis calapparia*) used for bow and arrow heads.	Inland/Coastal	High	Moderate	High

Table 16.8 – Baseline Characterization of Preliminary Ecosystem Services – Provisioning and Cultural Services (cont'd)

Ecosystem Service	Habitat or Land Use	Description	Communities	Importance to Ecosystem Beneficiaries	Replaceability	Value
Provisioning Services						
Traditional practices (cont'd)	All (cont'd)	♦ Tree (*Heritiera litoralis*) used to make the triangular frame for the prawn fishing nets. ♦ Bark fibers from the tree (*Gnetum gnemon*) used to make traditional rope for string bags (bilums). All villages in the PAOI use traditional tools and materials for processing sago, and 94% and 85% of PAOI villages use traditional tools and materials, for hunting and fishing, respectively. Seventy five percent of villages in the PAOI perform traditional songs and dances at special occasions, and several villages reported using plants in secret chants to assist in hunting, fishing and growing crops. Traditional practices are often linked to specific plant or animal resources and known productive sites, limiting spatial alternatives.				High

* Ecosystem services rated as medium but discussed in the impact assessment by exception.

Table 16.9 – Baseline Characterization Preliminary Ecosystem Services – Regulating, Maintaining and Supporting Services

Ecosystem Service	Habitat/ Land Use	Description	Value
Control of erosion and sedimentation	Forests Mangroves Nearshore	Forest and riparian habitats regulate erosion and sediment delivery to streams, particularly on steep slopes where erosion potential is high, by providing a protective vegetative cover and reducing runoff (i.e., increasing infiltration). Natural vegetation currently covers more than 98% of the upstream study area. Largely undisturbed mangroves line the coast and estuarine areas in the southern part of the upstream Project area. These form part of the broadest coastal band of mangroves found in Papua New Guinea. Mangroves are also found along the coast and in estuarine areas of Caution Bay. Coral reefs and seagrass beds alleviate erosion from waves and storms. Seagrass meadows, such as those found in Caution Bay, stabilize the substrate, while coral reefs, such as the outer reefs in Caution Bay, provide a physical barrier protecting the coastline from waves and erosion.	High
Regulation of surface water and groundwater	Forest Rivers and waterbodies	Forests influence the volume of water available and the timing of water delivery. Stream-flow regulation by forests is due to processes in the forest canopy, on the surface and below the ground; a combination of interception, transpiration, evaporation, evapotranspiration and infiltration (FAO, 2019). The hills and ridges of the study area form the headwaters of the local streams, which eventually feed into the larger Purari River delta and its three main distributaries. The isolated perched, shallow groundwater occurring in the superficial and weathered material, particularly in the areas of steep slopes and incised valleys in PRL-15, is likely to act as an important recharge source for the base flow of streams and creeks.	High
Regulation of natural hazards	Forest Rivers and waterbodies Mangroves Nearshore	Ecosystems, e.g., forest, wetlands, floodplains, mangroves, coral reefs and seagrass beds, particularly those that are intact, assist in regulating natural hazard frequency and intensity, including floods, cyclones, tsunamis and landslides.	High
Regulation of air quality	Forest Rivers and waterbodies	Natural habitats (e.g., forests and lakes) can impede the movement of airborne substances (e.g., particulate matter and gaseous emissions) by providing a physical barrier. These habitats and the organisms in them, also play a role in extracting and/or altering chemicals from, and in, the atmosphere.	Low

Table 16.9 – Baseline Characterization Preliminary Ecosystem Services – Regulating, Maintaining and Supporting Services (cont'd)

Ecosystem Service	Habitat/ Land Use	Description	Value
Regulation of climate	Forest Rivers and waterbodies Mangroves Nearshore Offshore	Ecosystems in the study area influence the climate by absorbing greenhouse gases; and they can influence local variations in temperature, precipitation, and other climatic factors, e.g.: ♦ Forests, soils, geological formations and oceans all support carbon sequestration, whereby carbon dioxide is removed from the earth's atmosphere and stored in the long term, helping to reduce greenhouse gases and regulate the planet's climate. ♦ Forests absorb moisture through plant roots and subsequently release vapor into the atmosphere (i.e., evapotranspiration). ♦ In upland areas, cloud and fog are an important moisture source for most of the year, with areas subject to the most cloud receiving the most rain. ♦ Water evaporation from rivers, waterbodies and the ocean into the atmosphere acts as a greenhouse gas, helping regulate the earth's temperature. ♦ Seagrass meadows, marine algae and phytoplankton store carbon (blue carbon) acting as important carbon dioxide sinks.	Medium
Water purification and waste treatment	Forest Rivers and waterbodies	Ecosystems in the study area (e.g., forests, streams and wetlands) play a role in filtering and decomposing organic wastes and pollutants in water and assimilating and detoxifying compounds through soil and subsoil processes. In addition, ecosystems buffer the effects of erosion, and sediment and pollutant runoff into waterways, thereby assisting with regulating the health of river systems.	Very High
Regulation of soil quality	Forest Rivers and waterbodies	Ecosystems in the study area assist in sustaining the soil's biological activity, diversity, and productivity. Ecosystems also assist in storing and recycling nutrients and gases. Vegetation cover is a key component of this process, which assists in regulating soil quality. In addition, water regulation through the soil profile can assist with filtering and breaking down contamination and pollutants, and can assist with assimilating uncontaminated forms of organic waste, while contributing to soil moisture content, and thus habitat suitability for organisms that enhance nutrient regulation and fix nitrogen. Organic matter in soil provides energy for all microbial and faunal activities, allowing them to build the micro-aggregate structures that control soil hydraulic properties, further conserving organic matter (Millennium Ecosystem Assessment, 2005); FAO, 2005).	Low

Table 16.9 – Baseline Characterization Preliminary Ecosystem Services – Regulating, Maintaining and Supporting Services (cont'd)

Ecosystem Service	Habitat/ Land Use	Description	Value
Regulation of disease	Forest Rivers and waterbodies	Intact ecosystems, such as those across much of the study area (see Section 7.7), provide natural protection against the transmission of infectious disease. Changes to habitat or forest cover and increasing vector breeding sites or reservoirs of host distribution; and biodiversity, including the loss of predators and changes in the host population density, are two of the main biological mechanisms altering the occurrence of infectious diseases (Millennium Ecosystem Assessment, 2005).	High
Regulation of pests	Forest Rivers and waterbodies	Ecosystems can resist the establishment, growth, survival and reproduction of invasive species, such as those identified in the study area. Ecosystem condition affects its resilience; and, in general, resistance of an ecological community against invasion by introduced species, increases with species and functional-type richness (Millennium Ecosystem Assessment, 2005; Balvanera et al., 2006 in TEEB, 2010). This is likely to be related to the level of disturbance and the intactness of ecosystems.	Medium
Pollination and seed dispersal	Forest	Ecosystems in the study area, comprising rich assemblages of fauna vertebrates and invertebrates, play a critical role in dispersing seeds and transferring pollen between flowering plants.	Medium
Seedbank for natural regeneration	Forest	The presence of intact topsoil is a key component to the success of natural regeneration. The topsoil containing the soil seed bank is essential for providing a medium for vegetation regeneration across disturbed surfaces and may contain almost 1,000 viable seeds per square meter in the top 5 cm of soil (Rogers & Hartemink, 2000). Almost all these seeds (99%) are pioneer species with fast growth rates and short life cycles that quickly reproduce to replenish the soil seed bank, and their seeds remain viable in the soil for several years from which forest regeneration occurs.	High
Provision of habitat	Forest (including the subterranean environment) Mangroves Rivers and waterbodies Nearshore Offshore	Habitat is a natural space that maintains species populations and protects the capacity of ecological communities to recover from disturbances. Habitat in the study area includes: ♦ Terrestrial biodiversity focal sites. ♦ Mangroves are nurseries for aquatic fish and invertebrate species, and are key to maintaining the commercial fisheries. ♦ Rivers and estuaries provide nursery habitat for juvenile and sub-adults, including protected elasmobranch species. ♦ Seagrass meadows found in Caution Bay provide food and refuge for marine fauna, including juvenile fish and invertebrates, and commercial and subsistence fauna. ♦ Coral reefs, such as those found in Caution Bay, are feeding and nursery grounds for marine fauna. ♦ Offshore waters and the seabed in the Gulf of Papua along the offshore export pipeline route provide habitat for commercially harvested species, pelagic and demersal fishes, marine reptiles, and mammals of conservation significance.	High

Table 16.9 – Baseline Characterization Preliminary Ecosystem Services – Regulating, Maintaining and Supporting Services (cont'd)

Ecosystem Service	Habitat/ Land Use	Description	Value
Nutrient cycling	Forest Mangroves Rivers and waterbodies	The flow of nutrients through ecosystems underpins all other ecosystem services, as it provides elements necessary for life, and alterations to the nutrient cycle can cause nutrient excesses or deficiencies (Millennium Ecosystem Assessment, 2005). Decomposition of organic matter is crucial to nutrient availability, as plant uptake is almost exclusively in the inorganic form (Parton et al., 1988, as cited in Millennium Ecosystem Assessment, 2005). In the study area: ♦ Forests produce organic matter enabling nutrients to be added to the cycle. ♦ Mangroves can act as nutrient sources or sinks. ♦ Fluvial discharges from rivers, such as the Purari River distributaries, deliver or transport nutrients between habitats and into the pelagic zone. ♦ Seagrass meadows trap and recycle nutrients. ♦ Upwelling of nutrient-rich cooler waters from deeper offshore areas brings nutrients to the warmer, shallower nearshore habitats. Also see 'Regulation of soil quality'.	Medium
Primary production	Forest Mangroves Rivers and waterbodies Nearshore Offshore	Primary production is the formation of biological material by plants through photosynthesis and nutrient uptake. The higher the diversity of primary producers, the higher the diversity of primary consumers (e.g., herbivores) (Balvanera et al., 2006, in TEEB, 2010). In the study area: ♦ Natural vegetation covers more than 98% of the terrestrial study area. ♦ Mangroves provide organic matter or are a carbon source to the aquatic environment. ♦ Seagrasses, mangroves, micro- and macroalgae, and phytoplankton are primary producers in the aquatic environment. ♦ Primary production in pelagic environments of the Gulf of Papua is generated from a combination of autotrophic (photosynthetic, i.e., phytoplankton) and heterotrophic (non-photosynthetic, i.e., microbial) sources. Benthic-pelagic coupling is strong in the Gulf of Papua, with detrital input from rivers driving nearshore primary productivity (Robertson et al., 1998).	Medium
Water cycling	Forest; Mangrove Rivers and waterbodies; Nearshore; Offshore	Water flows through ecosystems in solid, liquid, or gaseous forms; and this occurs in the study area via the processes of atmospheric circulation and precipitation; evaporation, evapotranspiration and condensation; surface runoff and stream and river flow; groundwater infiltration, discharge and storage; and freshwater and oceanic storage.	Medium

Table 16.9 – Baseline Characterization Preliminary Ecosystem Services – Regulating, Maintaining and Supporting Services (cont'd)

Ecosystem Service	Habitat/ Land Use	Description	Value
Soil formation	Forest Rivers and waterbodies	Soils support many ecosystem services in the study area, including food, fuel, fiber and building materials, by providing baseline infrastructure, such as acting as a medium for vegetation growth (South East Queensland Catchments, 2017).	Low
Genetic resources	Forest Mangroves Rivers and waterbodies Nearshore Offshore	Genetic resources contain information pertaining to a species' evolutionary history (i.e., inherited changes between generations). In the context of the study area where extensive natural vegetation coverage exists, genetic resources are important, as genetic variability within a species supports genetic variability within an ecosystem, thus supporting a variety of other identified ecosystem services. In addition, they contribute to the capacity of organisms to adapt to changed environmental conditions and/or regulate pests and diseases.	Medium

16.4.3 Overview of Priority Ecosystem Services

Table 16.10 summarizes the analysis conducted for the baseline characterization, which identified the priority ecosystem services for the Project. Those that were not rated as high or very high were screened out of the assessment. Identification and assessment of potential impacts on these ecosystem services, focusing on site-specific analysis in relation to the location, extent and nature of Project activities, are discussed in Sections 16.5 and 16.7.

Table 16.10 – Priority Ecosystem Services

Ecosystem Service	Description	Value
Provisioning Services		
Wild food (plants, nuts and fruits)	Forest plants that coastal villages use as a supplementary food to crops.	High
Food (crops)	Planted crops in gardens for coastal villages.	High
Fuel (firewood)	Firewood is used as a primary source of fuel by coastal and inland villages.	High
Timber and wood products	Forest timber is used in the PAOI for building materials, particularly house posts and canoes. House posts are in short supply for some communities.	High
Fresh water (domestic use)	Many coastal and inland villages rely on rivers or creeks as their main source of drinking water.	High
	Orokolo villagers use groundwater for drinking and washing. There are few alternatives, and sampled wells are high in coliforms.	Very High
Rivers and nearshore marine environment (transportation)	Coastal and inland villagers rely on rivers for transportation in the PAOI. Coastal villagers rely on travel along the Orokolo coastline for fishing and access to markets.	High
Commercial marine fisheries	Fishing companies rely on fishing activity for income and employment.	High
Commercial forestry	Logging companies rely on logging activity for income and employment.	High
Cultural Services		
Cultural sites	Coastal and inland villages report spirit sites of high local importance in the landscape.	Very High
Traditional practices	Coastal and inland villages rely on natural resources for making traditional tools, processing sago, body decorations for performing songs and dances, and in sorcery.	High
Regulating, Maintaining and Supporting Services		
Control of erosion and sedimentation	Intact vegetation protects against erosion and increased sedimentation in aquatic environments.	High
Regulation of surface water and groundwater	Recharge and quality of water sources are important as a source of domestic supply and as a source for aquatic ecosystems.	High
Regulation of natural hazards	Intact forest, mangrove and nearshore ecosystems protect villages and Project infrastructure from natural events such as flooding, fire or tsunamis.	High
Water purification and waste treatment	Ecosystems play an important role in filtering wastes and pollutants from water and soils.	Very High

Table 16.10 – Priority Ecosystem Services (cont'd)

Ecosystem Service	Description	Value
Regulating, Maintaining and Supporting Services		
Regulation of disease	Natural vegetation and surface waters play a key role in regulating disease.	High
Seedbank for natural regeneration	The presence of intact topsoil is a key component to the success of natural regeneration.	High
Provision of habitat	Habitat is a natural space that maintains species populations and protects the capacity of ecological communities to recover from disturbances.	High

16.5 Identification of Potential Impacts

The Project has the potential to impact on ecosystem services through clearing of vegetation and garden areas that provide food; restricting community access to food resources; changes (through discharges) to surface and groundwaters; detrimental biophysical impacts that cause changes to organism abundance, diversity or distribution. Potential benefits may include providing alternatives to subsistence agriculture and fishing through new economic opportunities.

This section outlines the potential impacts of these activities on the priority provisioning, cultural and regulating, maintaining and supporting ecosystem services. Potential impacts are discussed in relation to the communities residing in and around each of the three onshore Project areas, i.e., PRL-15, the onshore export pipeline corridor and the river transport corridor (see Figure 13.1), and impacts that could occur offshore, which could be relevant to communities residing in Orokolo Bay and around the Purari River delta.

Ecosystem services is a transdisciplinary topic, combining social, cultural and environmental factors. Therefore, this assessment draws from multiple chapters from this EIS, including Chapters 11, 12, 13, 14, 15 and 17.

There is uncertainty on the possible scale of in-migration in relation to the Project, therefore a conservative approach has been applied in the assessment of potential related impacts on Ecosystem Services.

16.5.1 Provisioning Services

16.5.1.1 Direct Loss of Wild Plant Foods

The availability of forest habitat for wild plant food provisioning is a priority ecosystem service only for coastal communities, as inland communities have greater access to forest resources (see Table 16.8). Native forests provide habitat for the highest proportion of wild foods, which are mostly trees and palms that provide edible fruits and nuts. Extensive areas of sago palm occur in Swamp woodland (Wsw) and extensive areas of almost pure nipa palms, which provide edible nuts, occur in the Mangroves ecological zone. These areas occur primarily along the export pipeline corridor and Orokolo Bay.

Construction-related clearing could remove or reduce food sources near villages and/or cause associated forest degradation, causing villagers to have to spend more time and/or effort to source these foods. Table 16.11 shows the estimated areas of sago dominated forest and vegetation complex with sago to be cleared along approximately 5 km of the onshore export pipeline route. The extent of the clearing of sago dominated forest along the onshore export pipeline route close to villages is less than 8 ha.

Table 16.11 – Potential Impacts on Food Sources in the PAOI

Vegetation/Land use	Area in the Study Area (ha)	PRL-15				Non PRL-15			
		Clearance (ha)	Clearance (%)	Degradation (ha)	Degradation (%)	Clearance (ha)	Clearance (%)	Degradation (ha)	Degradation (%)
Primary Hill forest (H)	250,982	554.28	0.22	1,951.39	0.78	1.17	0.00	9.39	0.00
Logged Hill forest (H)	89,996	7.13	0.01	43.77	0.05	13.93	0.02	97.64	0.11
Primary Alluvial forest (P)	85,001	72.91	0.09	151.21	0.18	33.68	0.04	226.83	0.27
Logged Alluvial forest (P)	30,340	85.60	0.28	226.54	0.75	70.41	0.23	461.81	1.52
Swamp forest (Fsw)	111,460	0.00	0.00	0.0	0.00	65.43	0.06	423.84	0.38
Mangrove (M)	60,363	0.00	0.00	0.0	0.00	0.21	0.00	1.57	0.00
Littoral forest (B)	178	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00
Sago-dominated*	43,232	0.00	0.00	0.0	0.00	7.92	0.02	52.81	0.12
Vegetation complex with sago #	20,734	0.00	0.00	0.0	0.00	65.43	0.32	423.84	2.04
Wild stands of sago woodland ^	43,232	0.00	0.00	0.0	0.00	7.92	0.02	52.81	0.12
Gardens and hill forest (Hm5, Hs5)	112	0.00	0.00	0.0	0.00	0.0	0.00	NA	NA
Gardens and sago cultivation (O)	1,370	0.00	0.00	0.0	0.00	6.42	0.47	NA	NA

Notes: The study area refers to the area used for terrestrial biodiversity mapping, shown in Figure 7.16. * Sago-dominated is all the FIMS polygons of pure Wsw plus vegetation complexes where Wsw is the dominant vegetation type (i.e., Wsw/Gsw, Wsw/Fsw and Wsw/Hsw). # Vegetation complex with sago includes all vegetation complexes where Wsw is the subordinate vegetation type (i.e., Fsw/Wsw, Gsw/Wsw, Hsw/Wsw & Po/Wsw). ^ Wild stands of sago woodland are sago-dominated.

Clearing in PRL-15 will be remote from villages and is not expected to affect the availability of wild plant foods for Poroi 1, Mapaio Fish Camp or the Purari Airstrip House. Clearing across the Purari River from Aivai will be for a pipe yard and construction camp; but will be temporary in nature.

In-migration and induced access could increase pressure on wild foods; however, in-migration will vary in the Project area and is considered potentially more important in and around PRL-15, where wild food resources are largely replaceable. Thus, the reduction in availability of wild foods due to induced in-migration is considered negligible and is not assessed further. Chapter 13 discusses Project-induced in-migration and associated mitigations in further detail.

16.5.1.2 Loss of Food Gardens and Planted Sago

The main food crops that are grown in gardens are detailed in Part 18 of Volume 2. Some food grown in gardens and associated planted sago in coastal communities will be lost through land clearing associated with construction activities, particularly along the onshore export pipeline route in the Orokolo Bay area, which has the highest density of food gardens and planted sago in the Project area (Table 16.11 and Figure 16.3); however Table 16.11 shows that only 6.4 ha of gardens and planted sago will be cleared along the pipeline right of way.

Planted sago also occurs along the east and west banks of the Purari River in the river transport corridor and in PRL-15; however, clearing of planted sago or food garden resources is not predicted to occur in either of these parts of the Project area.

In-migration and unplanned community expansion could increase pressure on the land available for crop cultivation, particularly for the Orokolo Bay coastal communities or in communities along the onshore export pipeline route; however, in-migration to these areas is not predicted to be high (see Chapter 13). Thus, the impacts of increased pressure on food gardens and planted sago are considered negligible and are not assessed further.

Project activities could introduce new weed species, which have the potential to degrade food gardens; reduce productivity; increase manual labor; and compromise traditional cultivation practices. Construction activities need to occur near gardens and cultivated areas for these impacts to occur. This will occur along approximately 5 km of pipeline as it approaches Orokolo Bay (Figure 16.3) and standard risk-based weed hygiene measures will be applied (see Chapter 11); therefore, the potential impacts on food gardens associated with the introduction or spread of weeds are considered negligible and are not assessed further.

16.5.1.3 Reduced Access to Firewood

Firewood is an essential resource used by communities in the PAOI, as a fuel source for cooking. The Project has the potential to reduce the amount of firewood available near villages and to increase the time and/or effort required to source it, due to construction-related clearing or restricted access to coastal areas.

Firewood availability for residents of Poroi 1 and Mapaio Fish Camp is unlikely to be impacted by Project activities in PRL-15, as firewood is usually collected close to villages, and the Project will not be clearing near villages; therefore, reduction in the availability of firewood in and around PRL-15 is not discussed further.

Clearing is not proposed along the river transport corridor, so firewood availability to villages along the riverways will not be directly impacted due to Project activities; therefore, reduced firewood availability along the riverways is not discussed further.

PROJECT INFRASTRUCTURE IN RELATION TO FOOD GARDENS NEAR OROKOLO BAY

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FIGURE 16.3

Driftwood, collected from the beaches, is an important firewood source for coastal communities along Orokolo Bay. The construction footprint for the onshore export pipeline shore crossing will temporarily prevent access to that area of beach for firewood collection, and the driftwood that would otherwise have washed up on this area, may wash up on another clan's area of beach.

This could temporarily affect the collection and distribution of this resource for nearby villages of Iuku and Mareke.

16.5.1.4 Reduced Availability of Timber and Wood Products

Variation in the preferred house post species occurs across the PAOI, depending upon which species grow near villages. The preferred house posts are the most durable timbers that are in smaller size-classes growing near a village. House post species, particularly kwila (*Intsia bijuga*), which is the preferred species for riverway communities downstream of Pawaia territory, growing close to waterways are also of high value since they can be floated downstream to riverway villages. The Pawaia communities have access to hill forest that supports a greater diversity of tree species compared to the alluvial forests.

Preferred house posts are already in short supply for some communities, so coconut palm stems are used as a less durable replacement. This is due to clearing for subsistence agriculture in coastal communities and overharvesting in some of the river transport corridor communities on the lower reaches of the Purari River.

Dugout canoes are the main form of transport for most villages in the PAOI, except for inland villages such as Paevera, where there is no navigable waterway. Individual households own between one and five canoes suggesting widespread demand for canoe trees (see Part 18 of Volume 2); however, while canoes are an important asset, they generally last for two to three years and do not need to be replaced often.

Canoe trees are usually preferentially harvested from forest close to waterways. Canoe trees for the Pawaia are often harvested from hill forest up to one kilometer inland, made in the forest and then dragged to the nearest creek or river. Project-related clearing of large-diameter trees, i.e., more than 50 cm diameter at breast height near waterways, has the potential to remove canoe tree resources used by villagers, which may increase the time and/or effort to source, harvest and transport them. This is only a potential impact for Mapaio Fish Camp and Poroi 1, as other communities are much further from Project-related clearing.

16.5.1.5 Reduced Quantity and Quality of Fresh Water for Domestic Use

Project-related water extraction, wastewater discharges or accidental spills, and increased pressure from indirect effects, such as in-migration, may reduce the fresh water quality and quantity available for community use. Communities may have to source alternative supplies and/or use lower-quality supplies, which could cause declines in community health.

Water abstraction from the Purari River for the CPF and additional sediment from Project activities entering the Purari River will have negligible impact on water availability and quality, given the existing high sediment loads; therefore, these activities are not discussed further.

No communities in PRL-15 depend on surface waters from Boa Creek and Hou Creek, where water may be extracted for Project use; therefore, water extraction from these creeks is not discussed further.

Chapter 11 discusses the potential for trenching at the shore crossing in Orokolo Bay to cause fresh groundwater drawdown in nearby village wells. This could reduce the freshwater supply to coastal communities that rely on a thin lens of freshwater overlaying saline water.

Wastewater discharges or accidental releases could contribute to reduced water quality and reduced use for domestic purposes. A reduction in water quality could cause reduced use of these sources for domestic use, cause stress and anxiety about consuming these supplies, and ultimately cause more time spent sourcing alternate supplies.

In-migration and induced access could increase pressure on the availability and quality of fresh water. Fresh water is readily available (via the Purari River, family storage tanks) to communities in and around PRL-15, where in-migration is predicted to be highest throughout the PAOI, Therefore, the reduction in the quantity and quality of fresh water due to induced in-migration is considered negligible and is not assessed further. Chapter 13 discusses Project-induced in-migration in further detail.

16.5.1.6 Temporary Disturbance to Transport

Rivers are the main transport routes for communities to access schools, hospitals, markets, food gardens and sago processing sites (see Figure 13.1), and the predicted increase in barge traffic associated with Project construction activities could potentially disturb community use of the Purari River as a transport route to these sites and services.

Chapter 13 discusses the potential impacts associated with community use of the Purari River, nearshore marine environment and beaches along Orokolo Bay during pipeline construction; therefore, these impacts are not assessed further in this chapter.

16.5.1.7 Reduced Access, Catches or the Value of Commercial Fisheries

Two key commercial fisheries are relevant to the offshore Project area, i.e., the:

- Gulf of Papua Prawn Fishery.
- Torres Strait Tropical Rock Lobster Fishery.

The economic value of the Gulf of Papua Prawn Fishery is important to fishery license holders and the Government of Papua New Guinea. An overlap occurs between the commercial prawn fishery and the offshore pipeline route in two small reporting areas of the fishery (see Figure 8.26):

- Area 4 (Orokolo Bay) fishery reporting area.
- Area 5 (West Kerema Bay) fishery reporting area.

Chapter 15 discusses the potential for pipelaying activities to temporarily disrupt access to these fishery areas. The potential impact was considered negligible therefore it is not discussed further in this chapter.

Other potential impacts to the Gulf of Papua Prawn Fishery may include a temporary, localized, deterioration of water quality due to construction activities (e.g., suspended sediment plumes from trenching for the export pipeline, disposal of hydrotest water, and domestic wastewater and bilge water discharges from Project vessels).

The introduction of pests or pathogens from Project vessels and the possible impacts of underwater noise on aquatic fauna (i.e., associated with pipelaying activities and vessel movements) have also been considered. Implications for the prawn fishery are considered negligible and these impacts are not assessed further.

Commercial activities of the Torres Strait Tropical Rock Lobster Fishery, which is jointly managed by Australia and Papua New Guinea with an annual value of nearly AUD$20 million, are centered in the Torres Strait to southwestern Gulf of Papua well outside the PAOI; however, the ornate rock lobster mass migration to spawning sites at Yule Island and other reefs throughout Central Province (see Section 8.6.2.2) crosses the Gulf of Papua and the export pipeline route. The export pipelines may present a physical hindrance to this migration reducing the species population (Chapter 12).

16.5.1.8 Direct Loss of Commercial Forestry Resources and Royalties

Project construction in PRL-15 will clear an estimated 745 ha of commercial production forest based on data collected in 2016, of which 150 ha has already been logged and 595 ha has yet to logged. This would cause a potential loss of 10,710 m^3 of saw logs based on a mean merchantable volume of 18 m^3/ha (PNGFA, 1996) and assuming the 595 ha is not yet logged, is all accessible for logging, and has commercially viable volumes. This equates to a lost export value of US$1,071,000 for the commercial logging industry based on a conservative log export price of $US100/$m^3$ (ITT0, 2019),

Royalties on the logs could also be lost, reducing revenue for the customary landowners. Log royalties vary from K10 to K30/m^3, depending on the log export price (Hasagama, 2014), which would equate to a minimum value of lost royalties of K107,100.

Interactions between logging barges and Project river traffic may occur in the Purari River. This impact is discussed in Chapter 15. For cumulative impacts associated with deforestation and logging, see Chapter 17.

16.5.2 Cultural Services

16.5.2.1 Loss of Access to Cultural Sites

Chapter 14 provides a description of potential impacts on tangible cultural heritage and relevant management measures, including the potential benefits associated with implementation of a Cultural Heritage Management Plan.

Potential loss of access to cultural sites is covered in Chapter 14 and is not assessed further in this chapter.

16.5.2.2 Loss of Knowledge of Traditional Practices

Use of plants and animals for traditional practices requires a diverse range of species that are mostly widely present across hill and alluvial forest, and are used mostly in small amounts. Impacts are likely to be higher if forest is cleared near villages or food gardens, as these forest resources are easily accessed.

Potential impacts could also occur for fauna resources that are used in traditional practices and are highly valued, e.g., the availability of preferred bird feathers and animal skins used for body decoration in traditional ceremonies could be reduced, reflecting degradation of fauna habitat and ongoing disturbance from operational activities causing changes to fauna distribution or abundance. Reductions in fauna populations due to increased hunting (through induced access or in-migration), are expected to be minimal once mitigations are applied (see Chapter 11 and Chapter 13).

The potential for a loss of traditional knowledge and intergenerational transfer of knowledge due to less time being spent undertaking traditional practices as an indirect result of the economic

opportunities offered by the Project is discussed in Chapters 13 and 14 and is not assessed in this chapter.

16.5.3 Regulating and Maintaining Services

16.5.3.1 Loss of Ecosystem Function to Control Landform Stability and Erosion

Chapter 11 identifies that Project activities, particularly excavations and earthworks in PRL-15 and along the onshore export pipeline route, may reduce landform stability, increasing the incidence of landslips or mass movements.

Potential impacts associated with major natural hazards and unplanned events, such as landslips due to seismic events, are considered in Chapter 18.

16.5.3.2 Loss of Ecosystem Function to Regulate Surface Water and Groundwater

Chapter 11 describes the potential Project impacts to hydrology and groundwater, highlighting the potential for changes to hydraulic processes, reductions in stream flows, and groundwater contamination. The impacts of changes to fresh water on local communities is discussed in Section 16.5.2.1.

Key ecosystem services, such as water purification (Section 16.5.3.4), water-retention and climate regulation, are also connected to the hydrological cycle (Grizzetti et al., 2016). Surface water and groundwater regulation provides fresh water to ecosystems and local communities, and can reduce flood effects (Grizzetti et al., 2016).

Project activities, such as clearing; dredging; water abstraction; or building dams, culverts or water crossings, have the potential to disrupt natural surface flows or groundwater recharge. Changes to an ecosystem's natural hydrology and sediment delivery processes have the potential to inhibit the regulatory function of that ecosystem; however, given the minor impacts predicted in Chapter 11, the potential Project impacts on the ecosystem function to regulate surface water and groundwater is anticipated to be negligible and is not assessed further.

16.5.3.3 Loss of Ecosystem Function to Regulate Natural Hazards

The PAOI is subjected to flooding, e.g., near the proposed CPF in PRL-15, landslides and coastal erosion. These are natural events; however, the Project may impact the regulatory function of natural environments by clearing natural vegetation, so that landslides and flooding could become more regular and/or severe. This could be exacerbated by climate change, which is predicted to increase the intensity and frequency of extreme weather and climatic events (Australian Bureau of Meteorology and CSIRO, 2011).

The potential for Project activities to destabilize landforms and trigger landslides is assessed in Section 11.1.5.1 for the various landform types in the PAOI. Clearing forest on slopes increases landslide potential. Storm runoff from Project roads and tracks that generate infiltration excess, can increase landslides and associated surface erosion losses. Road cuts that intercept subsurface flows can exacerbate landslide potential (Sidle et al., 2006). Landslides typically cause the complete loss of vegetation cover and topsoil, all of which is deposited on forest on the lower slopes, causing further forest deterioration.

16.5.3.4 Loss of Ecosystem Function to Regulate Water Purification and Waste Treatment

Ecosystems in the Project area play an important role in filtering and purifying water, and assimilating, detoxifying or sequestering waste through soil or aquatic processes, thereby avoiding harmful effects on humans and the environment.

Activities that are most likely to constrain the regulation of water purification and waste treatment include land and topsoil clearing, modifications to surface waters in and around PRL-15 (see Chapter 11), and the removal or impairment of the aquatic organisms responsible for waste treatment.

Even small emissions to water could have an adverse impact on water quality, with flow-on effects to public health (see Chapter 13), if Project activities impair this ecosystem service. Eutrophication could also occur degrading aquatic habitats and harming species.

16.5.3.5 Loss of Ecosystem Function to Regulate Vector-borne Disease

Natural habitats can influence the spread of vector-borne disease, such as malaria, dengue and Ross River fever, to humans. As discussed in Chapter 13, malaria is the dominant vector-borne disease in the PAOI, and changes to environmental (e.g., through the creation of habitat) and social conditions have the potential to increase the frequency or severity of outbreaks.

The most direct way the Project can influence vector-borne disease regulation is through modifying natural environments, e.g., increasing areas of standing water, which can act as mosquito breeding areas, and increasing the number of people exposed to the disease.

Project impacts on the ecosystem's ability to regulate disease is negligible given the relatively small areas that the Project will impact relative to the amount of regulating environment available and Project mitigation measures; therefore, these impacts are not assessed further.

16.5.3.6 Loss of Topsoil and the Seedbank for Natural Regeneration

The presence of intact topsoil is a key component to the success of natural regeneration and can be lost from construction-related clearing and associated erosion.

In addition to the soil seedbank, seed rain is also important for maintaining natural regeneration and is a useful seed source for disturbed sites. Seed rain in larger clearings mostly occurs from wind-dispersed seed.

Project-related clearing is minor and localized (see Chapter 11); therefore, impacts on the natural regenerative capacity of the forest ecosystem service is negligible and is not assessed further.

16.5.3.7 Loss of Habitat Provision

Habitat is a natural space that maintains species populations and protects the capacity of ecological communities to recover from disturbances; the spatial extent and interconnectedness of habitats are important for recovery capacity. Within the study area, they include:

- Terrestrial biodiversity focal sites (see Section 7.7.7).
- Mangrove forests (see Section 7.7.7.2).
- Mangroves, as nurseries for a range of aquatic (fish and invertebrate) species (see Section 7.6.2.3).
- Rivers and estuaries, which provide nursery habitat for juvenile and sub-adults (see Part 5 of Volume 2).

- Seagrass meadows (found in Caution Bay), which provide food and refuge for marine fauna (see Section 8.5.2.4).
- Coral reefs, such as those found in Caution Bay, which are feeding and nursery grounds for marine fauna (see Section 8.2.2.5).
- Offshore waters in the Gulf of Papua and along the offshore export pipeline corridor, which provide habitat for pelagic fish and marine reptiles, and mammals of conservation significance (and commercial/subsistence importance) (see Section 8.5.3).

Project-related clearing and the laying of export pipelines will result in habitat loss. Chapters 11 and 12 identify and assess potential impacts to habitat and the species they support from Project activities, and therefore it is not assessed further in this chapter.

16.5.4 Non-priority Ecosystem Services

The impacts discussed in this section were not identified as priority ecosystem services during the screening process (see Table 16.10); however, beneficiaries rated them as of high-importance so they are considered in the following sections.

16.5.4.1 Impacts to Hunting and Fishing

Project noise from construction and/or operational activities around Mapaio Fish Camp, Poroi 1 and the Purari Airstrip House, including increased air or barge traffic during the construction phase, could cause local fauna to move out of the area, affecting hunting or fishing practices in and around these communities.

Chapter 15 describes the potential noise impacts from the CPF and Logistics Base in relation to sensitive receptors (i.e., villages). Chapter 11 discusses the potential impacts to fauna from noise and determines that it will just be near Project footprints and that residual impacts associated with noise disturbance to terrestrial species are rated as ***Minor***. Based on these assessments, the potential for construction or operating noise to impact local fauna to the extent that livelihoods are affected is considered negligible and not assessed further.

16.5.4.2 Loss of Wild Sago Stands

No wild stands of sago will be cleared from PRL-15; and less than 8 ha of wild sago dominated vegetation will be cleared from the onshore export pipeline route, which is 0.1% of the resource (Figure 16.4). Approximately 65 ha of vegetation where sago is a subordinate species will also be cleared, which is approximately 0.3% of the resource (see Table 16.11). Edge effects could also degrade a further 424 ha (2%) of this resource.

Wild stands of sago were not identified as a priority ecosystem service; however, forest plant food and wild sago stands are considered together in the residual impact assessment (Section 16.8.1.1), as wild sago is an important food source for many communities and is often found throughout the forest habitats where other wild plant foods are sourced, (i.e., swamp woodland (Wsw) and vegetation complexes where Wsw is dominant). Wild sago is not found in hill (H) or alluvial forest (P), which dominates much of PRL-15.

16.5.4.3 Changes to Participation in Artisanal Fisheries

The ornate rock lobster artisanal fishery is focused at Yule Island but occurs at reefs between Yule Island and Redscar Bay. Lobsters gather at the reefs to spawn from November to April,

PROJECT INFRASTRUCTURE IN RELATION TO WILD STANDS OF SAGO

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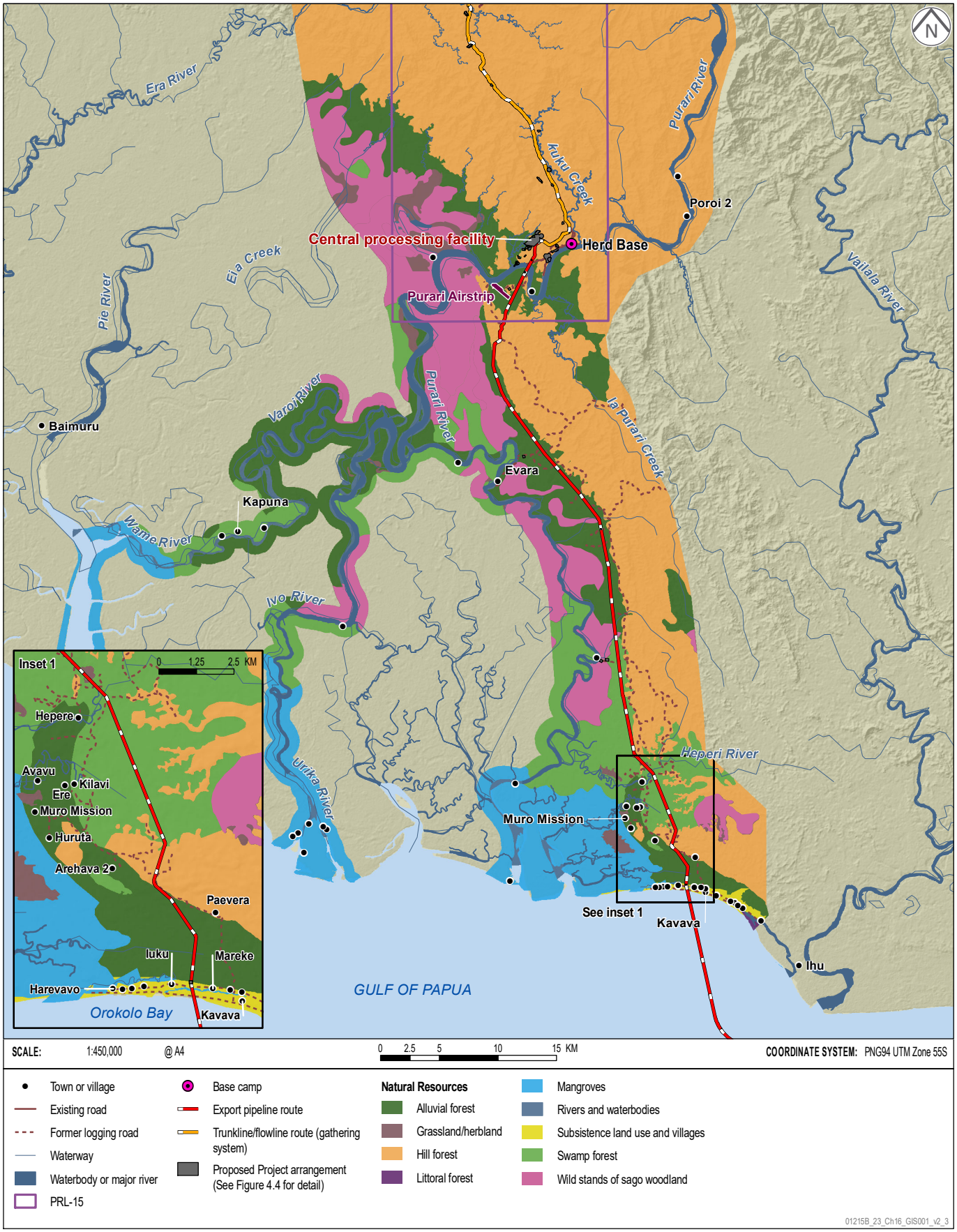
FIGURE 16.4



resulting in a seasonal artisanal and subsistence dive fishery (see Chapter 8). A reduction in the abundance of migrating lobsters arriving at the spawning reefs in this region could reduce this fishery, if the laid pipelines hinder migration (see Chapter 12).

Chapter 15 discusses the potential for the Project to temporarily disrupt access to artisanal fishing grounds in Orokolo Bay during pipelaying activities in the 3 nautical mile coastal zone; and considers this impact negligible and it is not assessed further.

Trenching activities in the unconsolidated muds in Orokolo Bay will mobilize sediment suspended into the water column, potentially causing localized and temporary impacts to fish, crabs, mollusks and prawns that are the focus of artisanal fisheries. Any trenching impacts are likely to be negligible, given the large area of this habitat available and the high ability of local fauna, including prawns, to adapt to naturally high levels of suspended sediment in this area; therefore, trenching impacting artisanal fisheries not assessed further.

Trenching for the offshore export pipelines in Caution Bay has the potential, to smother sensitive coral reef and seagrass habitats that support artisanal fisheries with mobilized sediment. These marine habitats are less adapted to high sediment exposure than those in Orokolo Bay, where much of the substrate is mud and large fluvial sediment inputs occur. Impacts on these habitats may temporarily reduce fish foraging habitat but are unlikely to measurably reduce species populations (see Chapter 12). Any impacts on artisanal fisheries due to trenching and pipelaying are; therefore, likely to be negligible and are not assessed further.

Construction activities at the shore crossings, pipelaying and ongoing operations of the export pipeline and barging activities through the Gulf of Papua to the Purari River have the potential to reduce water quality from planned wastewater discharges or accidental contaminant spills or leaks, and harm or kill marine species sought by artisanal fishers. These potential impacts are addressed in Chapter 12 and are therefore not assessed further in this chapter.

Project employment and business opportunities, and an increase in associated income (see Chapter 13) may indirectly contribute to a decline in artisanal fishing participation, which can induce subsequent positive and adverse impacts, including an improvement (i.e., due to an increase in diversity of food consumed) or a decline (i.e., due to an increase in consumption of unhealthy foods) in nutrition, a loss of traditional fishing knowledge, or an increase in demand for local seafood products, which could in turn increase pressure on nearshore fish stocks.

Predicting the positive or adverse impacts on fishery participation associated with an increase in employment or other business opportunities is difficult, as often multiple factors contribute to community investments in time, effort and other resources, and few longitudinal studies exist to draw from. EHL, (2012) identified a decline in artisanal fishing activity in Caution Bay due to increased employment during construction at the PNG LNG Facilities.

On balance, given the paucity of information to predict impacts of Project employment or income on artisanal fishing practices and the subsequent impacts relating to nutrition and health, traditional practices and changes to demand, any changes to artisanal practices (i.e., an increase or decrease in fishery participation) associated with changes to economic conditions cannot be assessed further with any level of confidence.

16.5.5 Summary of Potential Impacts

The Project has the potential to impact on priority ecosystem services, as summarized in Table 16.12.

Table 16.12 – Summary of Potential Impacts on Ecosystem Services

Ecosystem Service	Potential Impact
Provisioning Services	
Wild plant foods	♦ Small, direct loss of wild plant foods, including wild sago, in forest habitat near villages from land clearing along approximately 5 km of the export pipeline route, and an increase in the time/effort required to source these foods.
Gardens and planted sago	♦ Small, direct loss of planted sago and food gardens near villages in Orokolo Bay due to land clearing along approximately 5 km of the onshore export pipeline route and shore crossing.
Timber and firewood	♦ Reduced access to driftwood used for firewood during onshore export pipeline construction activities. ♦ Reduced availability of timber used for canoes and housing posts and increased time/effort required to source it for Mapaio Fish Camp and Poroi 1 communities due to land clearing activities.
Domestic water	♦ Reduced fresh water availability or quality for domestic use in villages along Orokolo Bay due to trenching activities, wastewater discharges or accidental hazardous material releases.
Commercial fisheries	♦ Reduced economic value of the Gulf of Papua Prawn Fishery due to water contamination from trenching activities or wastewater discharges. ♦ Reduced rock lobster migration to spawning sites affecting the species population and associated reductions in catches for the Torres Strait Tropical Rock Lobster Fishery, due to the Project pipelines hindering migration.
Commercial forestry	♦ Reduced harvestable timber from commercial concessions and a loss of revenue for logging concession holders due to land clearing. ♦ Loss of royalty payments for landowners due to clearing commercially harvestable trees.
Cultural Services	
Intangible heritage	♦ Direct loss of traditional knowledge of native flora and fauna due to a reduction in availability caused by land use changes.
Regulating and Maintaining Services	
♦ Loss of ecosystem function to control landform stability and erosion. ♦ Loss of ecosystem function to regulate natural hazards. ♦ Loss of ecosystem function to regulate water purification and waste treatment.	
Non-priority Services	
Wild plant foods	♦ Direct loss of stands of wild sago woodlands (approximately 8 ha) near villages due to land clearing along approximately 5 km of the onshore export pipeline route.
Artisanal fisheries	♦ Reduced catches for the artisanal fishery due to Project pipelines hindering rock lobster migration to spawning sites near Yule Island. ♦ Reduced species abundance or availability for artisanal fishing in Orokolo Bay or the Purari River delta due to temporary contamination from pipelaying, shore crossing construction or shipping.

Potential impacts to ecosystem services can be avoided or minimized through Project design which is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoidance of sensitive features, physical and economic displacement, priority ecosystem services, and minimization of project footprint, land clearing and disturbance, emissions and discharges) [ED013].

The following embedded design controls address potential impacts to the quantity and quality of fresh water for domestic use, commercial and artisanal fisheries:

- Adopt standard industry practices to prevent and protect against soil/water contamination, due to Project activities, such as:
  - Preparing hydrocarbon and chemical management procedures, as part of the Hazardous Materials Management Plan.
  - Building infrastructure on impervious surfaces where required
  - Providing permanent fuel and chemical stores, and maintenance and refueling areas with secondary containment of an appropriate volume to prevent loss to the environment or mixing with incompatible materials.
  - Installing interceptor pits or similar to collect contaminated surface water runoff and treat where required.
  - Installing tanks above ground with impermeable liners and bunds around tanks.
  - Regularly inspect and maintain the containers, storage and transfer infrastructure to prevent/control spills or leaks.
  - Installing readily accessible spill kits and training staff in their use.
  - Appropriately treating and disposing of any accidentally contaminated soils [ED003].
- Design Project infrastructure (including workforce accommodation) to minimize vector harborage (e.g., minimize pooling water, proper waste disposal) and human exposure (e.g., screening of doors and windows) to minimize spread of disease [ED035].
- The drilling will be performed using water-based mud [ED004].
- The landfill will be designed to comply with TOTAL's general specification for landfills, and will be designed, located, constructed and operated in general accordance with the intent of the Code of Practice for Sanitary Landfill Sites (DEC, 2001) and other applicable standard industry practices [ED005].
- Minimize chemical use and select chemicals considering the following criteria:
  - Lowest toxicity, lowest bioaccumulation potential and highest biodegradation;
  - Chemicals subject to bans or phase-outs [ED006].
- Use low-pressure detection alarms to detect pipeline leaks [ED007].
- Use fiber optic cable laid in the same trench to monitor pipelines. This cable will detect intrusions and ground movements [ED008].
- Locate valve stations along the onshore pipeline route to isolate pipeline sections if a leak occurs [ED009].
- The gathering and reinjection system, wells and export pipeline system will be routinely inspected, monitored and maintained, as part of operational controls (including pipeline instrumented pigging, well wellbore and reservoir pressure monitoring) [ED011].
- Hydrotesting will be undertaken to confirm weld integrity [ED012].
- The CPF will have an open drain system to manage rainwater; the system will have three separate networks:

- OD1 = permanently hydrocarbon-contaminated drains.
- OD2 = accidentally hydrocarbon-contaminated drains.
- OD3 = hydrocarbon-free drains.

Water from each system will be treated separately and discharged to the environment according to applicable limits [ED015].

- All OD1 waters will undergo water treatment by a hydrocarbon/water separation system prior to discharge to the Purari River according to applicable standards. All OD2 waters and water from primary treatment will be sent to an observation basin and treated by the hydrocarbon/water separation system prior to release if required. The clean OD2 water will be discharged to the Purari River. Non-contaminated stormwater (OD3) will be disposed of by natural percolation and evaporation [ED016].
- All OD1 water from wellpads will be collected in a dedicated closed tank and transported to the CPF for treatment prior to being discharged [ED017].
- The produced water generated at the CPF is to be injected back into the reservoir. Produced water will be retained in a tank with a capacity to contain five days of water production, as a backup if injection is unavailable [ED018].
- All vehicles (including vessels and aircraft) and machinery, plant and equipment will be regularly maintained to the manufacturer's specifications; defective items will be removed from service until they are repaired [ED019].
- Rainwater infiltration into hazardous materials storage areas will be prevented [ED020].
- Requirements for hazardous material transfer, overfill protection, and alarms will be implemented, e.g.,
  - Using dedicated fittings, pipes, and hoses specific to materials in tanks.
  - Providing secondary containment, drip trays, etc. at connection points or other possible overflow points.
  - Using dripless hose connections for vehicle tank and fixed connections with storage tanks.
  - Providing automatic fill shutoff valves on storage tanks to prevent overfilling.
  - Using piping connections with automatic overfill protection (float valve).
  - Fitting tanks with high-level alarms with both audible and visible annunciation [ED021].
- Ballast waters, liquid effluents and waste from vessels will be managed according to the MARPOL 73/78 requirements [ED022]
- Hydrotest water discharges will be managed according to applicable requirements [ED040].

The following embedded design control is relevant to regulating and maintaining services:

- All facilities and infrastructure will be constructed with surface-water drainage systems to reduce the potential for soil loss and degradation both on and off construction areas, and to limit soil erosion and discharge of sediment-laden water to local drainage lines and watercourses. Bridges and culverts will be designed to allow for high flow events following heavy rainfall and to replicate natural flow characteristics as far as practicable. The design is:

– To account for local rainfall conditions and catchment size of works areas.

– To allow avoiding unseasonal waterlogging

– To allow for rainfall events with an ARI of at least two years for temporary roads and up to 20 to 50 years for long-term major haulage routes as far as practicable [ED014].

In addition, the Project will maintain a grievance mechanism that is legitimate, accessible, predictable, equitable, right-compatible, and transparent [ED033].

16.6 Proposed Mitigation and Management Measures

Ecosystem services is a transdisciplinary topic, combining social, cultural and environmental factors. Accordingly, this section refers to mitigation and management measures identified in Chapters 11 to 15 which will effectively mitigate potential impacts on the priority ecosystem services.

When mitigation measures identified in previous chapters are insufficient to mitigate the potential impacts on the priority ecosystem services described in Section 16.5, additional measures have been identified. They are described in Table 16.13.

Table 16.13 – Ecosystem Services Mitigation Strategies and Management Plans

Potential Impact	Mitigation Measures	Management Plan
Provisioning Services		
♦ Small, direct loss of wild plant foods in forest habitat near villages from land clearing along the export pipeline route, and an increase in the time/effort required to source these foods.	♦ Measures to minimize vegetation clearing and associated impacts are described in Chapter 11. ♦ Measures to minimize impacts related to loss of wild plant foods are described in Chapter 13. Additional management measure include: ♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001].	Land Access Plan; Livelihood Development Plan;
♦ Small, direct loss of planted sago and food gardens near villages in Orokolo Bay due to land clearing along the onshore export pipeline route and shore crossing.	♦ Measures to minimize impacts related to loss of planted sago are described in Chapter 13. Additional management measure include: ♦ All sites proposed for development as part of the Project will be subject to a preconstruction survey to clearly identify acid sulfate soils, sensitive sites and habitats, e.g. roosting, breeding, nesting and threatened species sites, priority ecosystem services, archaeological sites, burial sites, sites of religious importance to be subject to specific mitigation measures [EM001].	Land Access Plan; Livelihood Development Plan;

Table 16.13 – Ecosystem Services Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Measures	Management Plan
Provisioning Services (cont'd)		
♦ Reduced access to driftwood used for firewood during onshore export pipeline construction activities. ♦ Reduced availability of timber used for canoes and housing posts and increased time/effort required to source it due to land clearing activities.	♦ Measures to minimize vegetation clearing and associated impacts are described in Chapter 11. Additional management measure include: ♦ Assess the efficacy of efficient wood burning stove programs in coastal Papua New Guinea and, if warranted, support extension services to promote their use in the PAOI in Orokolo Bay [ESM001].	Biodiversity Action Plan; Livelihood Development Plan
♦ Reduced freshwater availability or quality for domestic use in villages along Orokolo Bay due to trenching activities, wastewater discharges or accidental hazardous material releases.	♦ Measures to protect the quality and quantity of surface water and groundwaters are described in Chapter 11.	Water Management Plan
♦ Reduced economic value of the Gulf of Papua Prawn Fishery due to water contamination from trenching activities or wastewater discharges. ♦ Reduced rock lobster migration to spawning sites affecting the species population and associated reductions in catches for the Torres Strait Tropical Rock Lobster Fishery, due to the Project pipelines hindering migration.	♦ Measures to minimize impacts on marine water quality and on rock lobsters are described in Chapter 12.	Biodiversity Action Plan; Traffic and Transport Management Plan
♦ Reduced harvestable timber from commercial concessions and a loss of revenue for logging concession holders due to land clearing. ♦ Loss of royalty payments for landowners due to clearing commercially harvestable trees.	♦ Measures to minimize vegetation clearing, and associated impacts are described in Chapter 11. ♦ Measures to minimize impacts related to clearing of commercially harvestable timber and trees are described in Chapter 13.	Biodiversity Action Plan; Land Access Plan; Livelihood Development Plan
Cultural Services		
♦ Direct loss of traditional knowledge of native flora and fauna due to a reduction in availability or accessibility caused by land use changes.	♦ Measures to minimize vegetation clearing and fauna habitat degradation are described in Chapter 11. ♦ Measures to minimize impact on Cultural Heritage are described in Chapter 14.	Biodiversity Action Plan; Cultural Heritage Management Plan
Regulating and Maintaining Services		
♦ Loss of ecosystem function to control landform stability and erosion. ♦ Loss of ecosystem function to regulate natural hazards. ♦ Loss of ecosystem function to regulate water purification and waste treatment.	♦ Measures to avoid or control soil erosion, avoid landform destabilization and soil degradation and support natural surface and groundwater systems are described in Chapter 11.	Soil Management Plan; Water Management Plan; Site Restoration and Rehabilitation Plan

Table 16.13 – Ecosystem Services Mitigation Strategies and Management Plans (cont'd)

Potential Impact	Mitigation Measures	Management Plan
Non-priority Services		
♦ Direct loss of wild sago near villages due to land clearing along the onshore export pipeline route.	♦ Measures to minimize vegetation clearing, and associated impacts are described in Chapter 11. ♦ Measures to minimize impacts related to loss of wild sago are described in Chapter 13.	Land Access Plan; Livelihood Development Plan;
♦ Reduced catches for the artisanal fishery due to Project pipelines hindering rock lobster migration to spawning sites near Yule Island. ♦ Reduced species abundance or availability for artisanal fishing in Orokolo Bay or the Purari River delta due to temporary contamination from pipelaying, shore crossing construction or shipping.	♦ Measures to manage impacts to rock lobsters and to minimize impacts associated with offshore construction activities are described in Chapter 12. ♦ Measures to avoid and minimize impacts on water quality are described in Chapters 11 and 12. ♦ Measures to minimize interactions between Project and community vessels are described in Chapter 13.	Biodiversity Action Plan; Water Management Plan; Livelihood Development Plan Community Development Plan Stakeholder Engagement Plan

16.7 Residual Impact Assessment

The following section provides the assessment of residual impacts to landform and soils subject to the embedded design controls in Section 16.5.5 and the successful implementation of the proposed mitigation and management measures and management plans in Table 16.13. A summary of the residual impact assessments is provided at the end of this section, including when and where (in which Project phase and location) these impacts are expected to occur.

16.7.1 Provisioning Services

16.7.1.1 Direct Loss of Wild Plant Foods Including Wild Stands of Sago

Wild plant foods and wild stands of sago are attributed a ***High*** sensitivity rating, particularly as communities around Orokolo Bay depend on these food sources and have limited ability to source alternatives, as relatively little forest remains and the population along the coast is denser than other areas of the PAOI.

Preconstruction surveys will allow identifying wild sago stands that are important for local villages. Once construction of the onshore export pipelines has been completed, wild sago will be allowed to regenerate in previously cleared sections outside of the right of way. The Project will follow the process set out in the Land Access Resettlement Framework when Project activities have an unavoidable impact on livelihoods through the loss of wild sago stands or other wild plant foods.

The extent of clearing wild stands of sago, along the onshore export pipeline route near villages is rated as ***Negligible*** due to the small extent of the resource planned to be cleared, i.e., less than 8 ha, or less than 0.1%, of the resource, the ability of some of this area to be recultivated, and the embedded design controls identified in Section 16.5.5; therefore, the residual impact significance rating of direct loss of wild plant foods in the export pipeline corridor communities is assessed as ***Negligible***.

16.7.1.2 Loss of Food Gardens and Planted Sago

The Project area currently has no commercial agricultural production; however, subsistence food gardens exist that are essential for community livelihoods, particularly in the coastal areas up to

approximately 1.7 km north of Iuku. Sago is the main staple food for all the villages and an important famine food, as it is resilient to floods and drought. Planting and harvesting sago are the most important food production activities in the PAOI.

The sensitivity of both food gardens and planted sago is rated as ***High***, as these resources are a primary food source for communities in the PAOI.

Table 16.11 and Figure 16.3 show that an estimated 6.4 ha of cultivated land along 5 km of the export pipeline route, which includes an unknown proportion of planted sago, will be cleared or degraded.

One of the main issues with clearing any planted sago is that it is not immediately replaced, given the palm can take 12 or more years to mature sufficiently to be ready for processing (Lal, 2003). The projected clearing of cultivated land represents less than 0.5% of the resource in the coastal Orokolo Bay area (see Table 16.11); however, the impacts could be high for individuals or families if the area cleared contains large numbers of mature palms compared to clearing young sago palms.

Figure 16.3 indicates how the export pipeline route has been sensitively aligned to avoid food gardens along the onshore export pipeline route where possible. Preconstruction surveys will identify any additional established food gardens and planted sago along the route.

Food gardens cleared in the pipeline right of way for construction, may be allowed to be re-established in previously cleared sections outside of the right of way. The Project will follow the process set out in the Land Access Resettlement Framework when Project activities have an unavoidable impact on livelihoods through the loss of food gardens and planted sago.

The magnitude of the clearing, given the small areas to be cleared along the export pipeline route and the livelihood restoration or compensation, is rated as ***Negligible***; therefore, the residual impact significance assessment of direct loss of food gardens and planted sago is ***Negligible***.

16.7.1.3 Reduced Access to Firewood

Firewood is an important resource for all PAOI communities; however, supplies are plentiful in the PAOI; therefore, the sensitivity assigned to firewood as an ecosystem service is ***Medium***.

Construction of the export pipeline shore crossing will form a narrow, temporary corridor across the beach between Iuku and Mareke, and villager access to the beach and sand dunes will be maintained during construction wherever possible.

No long-term loss of access to driftwood is anticipated, as the shore crossing will not be closed to public access once construction is completed, allowing collection to resume as normal. Given these mitigations, the magnitude of any potential loss of firewood for export pipeline corridor communities is assessed as ***Negligible*** and the residual impact significance rating for a reduction in firewood availability and an increase in the time and/or effort to source it is assessed as ***Negligible***.

16.7.1.4 Reduced Availability of Timber and Wood Products

The sensitivity of timber and wood products as an ecosystem service is rated as ***Low***, due to less overharvesting, lower population densities and a greater variety of suitable tree species for inland communities along the inland river transport corridor and, in and around PRL-15, whereas the sensitivity rating for communities along the onshore export pipeline corridor, and particularly around Orokolo Bay, is ***Medium***, as the population is denser than further inland, fewer species are available and forested areas are under pressure from land-use related clearing.

Areas to be cleared near existing villages that have access to other timber resources are small, therefore, the magnitude of the potential impact is rated as ***Negligible*** for communities in and around PRL-15, and inland villages along the river transport corridor and onshore export pipeline route. This results in a residual impact significance assessment of ***Negligible***.

The magnitude of the impact is rated as ***Low***, for villages along Orokolo Bay, where any loss of suitable housing posts could represent a more significant loss due to pre-existing scarcity and a larger population. This results in a residual impact significance assessment for loss of timber and wood products around Orokolo Bay of ***Minor***.

16.7.1.5 Reduced Availability or Quality of Fresh Water for Domestic Use

The services that fresh water provides are essential for maintaining health, wellbeing and livelihoods, and few viable sources are available, which makes PAOI communities vulnerable to any decline in freshwater supply or quality. This results in a ***High*** sensitivity rating for fresh water for domestic use.

Chapter 11 describes the impacts of planned wastewater discharges and accidental hydrocarbon and chemical releases to the Purari River, and the potential impacts associated with trenching the export pipelines for the shore crossing in Orokolo Bay. All residual impacts, once embedded design controls and mitigation measures are implemented are assessed to be ***Negligible*** to ***Moderate*** (the latter rating being applicable to the potential impacts of small accidental hydrocarbon releases on the Purari River water quality and of the reduction in water availability in Orokolo Bay due to trenching activities at the shore crossing). Given the assimilative capacity and high flow volumes of the Purari River, and the availability and use of rainwater capture (tanks or drums) in riverways communities, the potential impact of accidental hydrocarbon release negatively affecting drinking water availability for river transport communities is assessed as ***Negligible*** providing a residual impact significance assessment of ***Negligible***.

Any potential impact to groundwater availability through trenching activities along the coast would be temporally limited and localized, and addressed via adaptive management where required. This is discussed in further detail in Section 11.2.5.2 and not considered further in this chapter.

16.7.1.6 Reduced Access, Catches or Value of Commercial Fisheries

Reduced Economic Value of the Gulf of Papua Prawn Fishery due to Water Contamination

The economic value of the Gulf of Papua Prawn Fishery is important to fishery licence holders and to the Government of Papua New Guinea, and the sensitivity of the fishery is rated as ***High***.

No direct impacts to prawns due to Project activities are predicted to occur; however, contamination of marine waters in the prawn fishery could cause water quality to deteriorate temporarily in a very small area, which could reduce the economic value of the fishery with respect to catch rates and accessibility. Market perceptions that the fishery catch is contaminated may also reduce the economic value of the fishery.

Considering embedded design controls; and mitigation and management measures that will be implemented to prevent, minimize, contain and clean up accidental contaminant leaks or spills in the marine environment, the residual impact significance assessment rating for marine water contamination is ***Negligible*** for planned wastewater discharges and ***Minor*** for accidental contaminant releases. The magnitude rating is assessed as ***Negligible****,* given the mitigation measures described in Chapters 12 and 15, and the large alternative area available for the fishery to operate in***;*** therefore, the residual impact significance assessment rating for contamination negatively impacting the Gulf of Papua Prawn Fishery is assessed as ***Negligible***.

Pipelines Hindering the Rock Lobster Migration with Associated Reduction in Catches for the Torres Strait Tropical Lobster Fishery

Commercial rock lobster stocks in the commercial fishery located in the Torres Strait and the far southwestern Gulf of Papua are contingent on a range of regional-scale biophysical processes. The presence of other breeding sites, larval supply from the Coral Sea, recruitment success and in-migration into the Torres Strait fishery zone from the Great Barrier Reef and other areas, and sequencing of the Gulf of Papua migration with age are among the main regional-scale drivers affecting commercial stocks.

The Torres Strait Tropical Rock Lobster Fishery is a managed fishery, and catch limits are set based on fishery-independent surveys and annual stock assessments. Reported commercial catches are highly variable year by year, as effort and lobster abundance fluctuate. Australian and Papua New Guinean fisheries' authorities have identified some key unknowns related to the fishery, such as the impact of unregulated artisanal fishery in Papua New Guinea, and the dynamics of larval supply and recruitment.

The sensitivity rating of the fishery is assessed as ***Medium***, as the fishery has some resilience to change due to its geographical extent and the management arrangements in place. Given this sensitivity, the magnitude of the impact that the export pipelines may hinder the rock lobster migration such that it affects this commercial fishery is assessed as ***Negligible***. This results in a residual impact significance assessment rating of ***Negligible***. This ranking is contingent on the mitigations listed in Chapter 12.

16.7.1.7 Loss of Commercial Forestry Resources and Royalties

Reduced Harvestable Timber from Commercial Concessions and a Resulting Loss of Revenue

The Project proposes to clear approximately 745 ha of forest that supports commercial timber production. Of this, at least 150 ha has already been logged; and, more of the remaining area is likely to also have been logged by the time Project construction clearing takes place.

The sensitivity of commercial forestry beneficiaries is rated as ***Low***, as the industry is easily adaptable to change, and considerable areas of this resource exist outside the Project footprint. The magnitude of the direct loss of forestry resources for commercial beneficiaries, considering the management measures proposed, is rated as ***Medium***, as the forestry resources may be unavailable to harvest before construction clearing due to their size or accessibility, and will also be unavailable in the PRL-15 Project footprint for the life of the Project. This provides a residual impact significance assessment rating of ***Minor*** for the loss of harvestable timber for commercial beneficiaries.

Loss of Royalty Payments for Landowners from Commercial Logging

Logging activities are complete in the export pipeline route at this time. The sensitivity of commercial forestry, as a source of income for landowning communities is rated as ***High***, and the magnitude of the potential impact is ***Low***, given the embedded design controls and mitigation measures proposed. This provides a residual impact significance assessment rating of ***Minor***.

16.7.2 Cultural Services

Chapter 14 describes the management measures proposed to mitigate Project-related impacts on intangible heritage. The potential for reduced availability of plants and animals used for traditional purposes due to in-migration and Project-related clearing will be managed by measures to document and maintain intangible heritage (see Chapter 14), manage in-migration (see Chapter 13) and by conducting preconstruction surveys to identify local sensitivities (see Chapter 11).

16.7.3 Regulating and Maintaining Services

Management measures to control erosion and sedimentation, landslides and impacts on surface water discussed in detail in Chapter 11 are expected to address the potential decrease in the ecosystem ability to regulate and maintain services.

16.7.4 Non-priority Ecosystem Services – Changes in Participation of Artisanal Fishing

Selling the surplus catch from artisanal fishing is opportunistic and has been declining over recent years, as people have sought other sources of income, and consumers have sought more access to store-bought foods; although, it remains an important source of income for some coastal communities. These changes to participation in artisanal fishing indicate community capacity to realize opportunities and adapt to change. This results in a sensitivity rating of ***Medium*** for artisanal fishing in the PAOI.

16.7.4.1 Pipelines Hindering Rock Lobster Migration to Spawning Sites Near Yule Island, with Associated Reductions in Catches for the Artisanal Fishery

The Project pipelines have the potential to reduce the artisanal lobster fishery in the area between Yule Island and Redscar Bay by hindering lobster migration.

Spatial alternatives in this fishery are limited, as lobsters arrive at nearshore reefs in this area over a defined migration season. The extent to which the export pipelines may hinder the lobster migration, such that the status of the artisanal fishery is affected, is uncertain. Adaptive management measures to mitigate possible impacts, including appropriate management responses as required, are described in Chapter 12; therefore, the magnitude is rated as ***Medium***, and the residual rating of this impact for communities that are involved in the fishery is assessed as ***Moderate***.

16.7.4.2 Water Contamination from Pipelaying or Shipping Impacting Artisanal Fishing in Orokolo Bay or the Purari River Delta

Impacts on water quality due to activities occurring at the Logistics Base and CPF are unlikely to impact the lower reaches of the Purari River delta and are assessed in Chapter 11 as being ***Negligible*** to ***Minor***.

Chapter 12 describes the management measures that will be in place to prevent, minimize, contain and clean up accidental contaminant leaks or spills in the marine environment. The residual impact due to a decrease of marine water quality was assessed as ***Negligible*** for planned wastewater discharges and ***Minor*** for accidental contaminant releases. Communities may avoid fishing in particular areas and for particular species if they believe that Project activities have contaminated the water; therefore, community engagement and water quality monitoring will be important tools for confirming the efficacy of mitigation strategies and communicating Project impacts or lack thereof.

Crabs and mollusks targeted by artisanal fishers are perhaps more susceptible to contaminant releases than more mobile species, such as finfish or prawns; however, the magnitude rating is ***Low*** since the impact is likely to be localized, temporary. The residual impact significance assessment rating for contamination of marine or estuarine waters impacting negatively on artisanal fishing for river transport corridor and export pipeline corridor communities is assessed as ***Minor***.

16.7.5 Summary of Residual Impact Assessment for Ecosystems Services

A summary of the assessment of residual impacts related to ecosystems services is provided in Table 16.14, including the Project phase and location when and where impacts are expected to occur. The table should be read with the mitigation measures provided in Table 16.13. All residual impacts are assessed to be ***Negligible*** to ***Minor***, except for the following impact, which is assessed to have a ***Moderate*** residual impact:

- Reduced catches for the artisanal fishery due to Project pipelines hindering rock lobster migration to spawning sites near Yule Island.

Table 16.14 – Summary of Ecosystem Services Residual Significance Assessment

Ecosystem Service Category	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation or Management Measure	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Provisioning Services							
Wild foods – plants	Vegetation clearing; onshore pipeline construction.	Small, direct loss of wild plant foods in forest habitat near villages from land clearing along the export pipeline route, and an increase in the time/effort required to source these foods.	Onshore export pipeline route	C	♦ See Chapter 11 ♦ See Chapter 13 ♦ EM001	High/Negligible	Negligible
		Direct loss of wild sago near villages due to land clearing along the onshore export pipeline route.		C		High/Negligible	Negligible
Food – crops	Vegetation clearing; onshore pipeline construction.	Small, direct loss of planted sago and food gardens near villages in Orokolo Bay due to land clearing along the onshore export pipeline route and shore crossing.	Onshore export pipeline route	C	♦ See Chapter 13 ♦ EM001	High/Negligible	Negligible
Fuel (firewood)	Onshore pipeline construction.	Reduced access to driftwood used for firewood during onshore export pipeline construction activities.	Onshore export pipeline route	C	♦ See Chapter 11 ♦ ESM001	Medium/ Negligible	Negligible
Timber and wood products	Vegetation clearing.	Reduced availability of timber used for canoes and housing posts and increased time/effort required to source it due to land clearing activities.	Onshore export pipeline route	C	♦ See Chapter 11 ♦ ESM001	Medium/Low	Minor
			PRL-15, river transport corridor			Low/Negligible	Negligible

Table 16.14 – Summary of Ecosystem Services Residual Significance Assessment (cont'd)

Ecosystem Service Category	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation or Management Measure	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Provisioning Services (cont'd)							
Freshwater (domestic use)	Logistics Transport	Reduced fresh water availability for domestic use due to accidental hydrocarbon release to the Purari River.	River transport corridor	C, O	♦ See Chapter 11	High/Negligible	Negligible
Commercial fisheries	Construction, including trenching, of Orokolo Bay export pipeline shore crossing.	Reduced economic value of the Gulf of Papua Prawn Fishery due to water contamination from trenching activities or wastewater discharges.	Offshore export pipeline route	C	♦ See Chapter 12	High/Negligible	Negligible
	Offshore pipeline construction.	Reduced rock lobster migration to spawning sites affecting the species population and associated reductions in catches for the Torres Strait Tropical Rock Lobster Fishery, due to the Project pipelines hindering migration.		C, O, D		Medium/ Negligible	Negligible
Commercial forestry	Vegetation clearing.	Reduced harvestable timber from commercial concessions and a loss of revenue for logging concession holders due to land clearing.	PRL-15, onshore export pipeline route	C, O	♦ See Chapter 11 ♦ See Chapter 13	Low/Medium	Minor
		Loss of royalties for landowners.				High/Low	Minor

Table 16.14 – Summary of Ecosystem Services Residual Significance Assessment (cont'd)

Ecosystem Service Category	Main Activity	Potential Impact	Location of Activity	Project Phase	Mitigation or Management Measure	Residual Assessment	
						Sensitivity/ Magnitude	Significance
Non-priority Services							
Wild foods – freshwater and marine species	Offshore pipeline construction.	Reduced catches for the artisanal fishery due to Project pipelines hindering rock lobster migration to spawning sites near Yule Island.	Offshore export pipeline route	C, O, D	♦ See Chapter 11 ♦ See Chapter 13.	Medium/Medium	Moderate
	Offshore pipeline construction; logistics and transport (barging along the Purari River).	Reduced species abundance or availability for artisanal fishing in Orokolo Bay or the Purari River delta due to temporary contamination from pipelaying, shore crossing construction or shipping.	Offshore export pipeline route, river transport corridor	C, O		Medium/Low	Minor

Note: C = Construction, O = Operations, D = Decommissioning and closure.

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Attachment 16.1
Defining the Scope and Information Needs for Ecosystem Services

Defining the Scope and Information Needs for Ecosystem Services

The World Resources Institute guidance (WRI, 2013) describes the need to establish the geographic boundary of the ecosystem services assessment and determine the data needs for each ecosystem service category.

The geographic boundary (i.e., study area) for the ecosystem services study was defined as the PAOI as described in Chapter 3. The PAOI incorporates the communities that are likely to be affected by the upstream Project, as listed in Section 9.5.1 of this EIS.

An integrated approach was used to collect the information required for the ecosystem services assessment. Data collection methods and the baseline reports, where information relevant to this ecosystem services baseline has been reported, are listed in Table 1 and described further in the following paragraphs.

Table 1 – Data Collection for the Ecosystem Services Baseline

Ecosystem Service	Method	Reports in Which Data Collected is Presented	Other Reports Reviewed
Provisioning Services			
♦ Wild foods ♦ Food (crops and livestock) ♦ Fuel (firewood) ♦ Timber and wood products ♦ Fibers and resins (non-timber) ♦ Freshwater (transportation) ♦ Marine (transportation) ♦ Commercial marine fisheries ♦ Commercial forestry	♦ Observations and informal discussions (terrestrial biodiversity and social survey team). ♦ Key informant interviews and focus group discussions during the community level survey. ♦ Structured questionnaire during the household survey. ♦ Semi-formal interviews during the ecosystem services survey.	♦ Upstream Terrestrial Biodiversity Baseline Report (Part 6 of Volume 2). ♦ Upstream Land and Natural Resources Baseline Report (Part 18 of Volume 2). ♦ Upstream Community and Demographics Baseline Report (Part 14 of Volume 2). ♦ Upstream Governance and Economics Baseline Report (Part 15 of Volume 2). ♦ Upstream Deforestation Baseline Report (Part 7 of Volume 2).	♦ Upstream Freshwater and Estuarine Biodiversity Baseline Report (Part 5 of Volume 2). ♦ Marine Biodiversity Baseline Report (Part 12 of Volume 2). ♦ Marine Fisheries and Resources Baseline Report (Part 13 of Volume 2). ♦ Upstream Community Health Report (Part 16 of Volume 2). ♦ Marine and River Traffic and Transport Baseline Report (Part 22 of Volume 2).
♦ Traditional medicine	As above	♦ Upstream Community Health Report (Part 16 of Volume 2). ♦ Cultural Heritage and Archaeology Baseline Report (Part 17 of Volume 2).	Not applicable
♦ Freshwater (domestic use)	♦ Key informant interviews and focus group discussions during the community level survey. ♦ Structured questionnaire during the household survey.	♦ Upstream Community and Demographics Baseline Report (Part 14 of Volume 2). ♦ Upstream Land and Natural Resources Baseline Report (Part 18 of Volume 2).	♦ Upstream Surface Water and Sediment Baseline Report (Part 3 of Volume 2). ♦ Groundwater Baseline Report (Part 4 of Volume 2). ♦ Upstream Community Health Report (Part 16 of Volume 2).

Table 1 – Data Collection for the Ecosystem Services Baseline (cont'd)

Ecosystem Service	Method	Reports in Which Data Collected is Presented	Other Reports Reviewed
Cultural Services			
♦ Cultural sites ♦ Traditional practices ♦ Plant/animal materials	♦ Key informant interviews and focus group discussions during the community level survey. ♦ Semi-formal interviews during the ecosystem services survey.	♦ Cultural Heritage and Archaeology Baseline Report (Part 17 of Volume 2). ♦ Land and Natural Resources Baseline Report (Part 18 of Volume 2).	♦ Upstream Community Health Report (Part 16 of Volume 2).
Regulating and Maintaining Services			
♦ Control of erosion and sedimentation ♦ Regulation of surface water and groundwater ♦ Regulation of natural hazards ♦ Regulation of air quality ♦ Regulation of climate ♦ Water purification and waste treatment ♦ Regulation of soil quality ♦ Regulation of disease ♦ Regulation of pests ♦ Pollination and seed dispersal ♦ Seedbank for natural regeneration	In-field observations from: ♦ Terrestrial biodiversity surveys ♦ Freshwater and estuarine surveys ♦ Groundwater, soils, terrain and geology surveys Sampling: ♦ Soil sampling ♦ Groundwater sampling ♦ Freshwater and marine water sampling Interviews: ♦ Key informant interviews and focus group discussions during the community level survey ♦ Semi-formal interviews during the land and natural resources survey	♦ Upstream Geology, Terrain and Soils Baseline Report (Part 1 of Volume 2). ♦ Upstream Hydrology and Meteorology Baseline Report (Part 2 of Volume 2). ♦ Upstream Surface Water and Sediment Baseline Report (Part 3 of Volume 2). ♦ Upstream Groundwater Baseline Report (Part 4 of Volume 2). ♦ Upstream Freshwater and Estuarine Biodiversity Baseline Report (Part 5 of Volume 2). ♦ Upstream Terrestrial Biodiversity Baseline Report (Part 6 of Volume 2). ♦ Marine Water and Sediment Quality Baseline Report (Part 11 of Volume 2).	♦ Upstream Air Quality Baseline Report (Part 19 of Volume 2). ♦ Seabed and Coastal Geomorphology Baseline Report (Part 9 of Volume 2). ♦ Physical Oceanography Baseline Report (Part 10 of Volume 2).
Supporting Services			
♦ Provision of habitat ♦ Nutrient cycling ♦ Primary production ♦ Water cycling ♦ Soil formation ♦ Genetic resources	As above	As above	As above

Information relevant to provisioning ecosystem services was collected through extensive consultation with communities in the PAOI during the social baseline surveys and ecosystem services interviews (reported in Part 18 of Volume 2). These activities specifically sought beneficiaries' views on the uses of resources from the natural environment, and of their perceptions of the importance of those resources.

Key information was captured through:

- The land and natural resources key informant interviews completed in 34 communities from all language groups, which collected systematic information on topics such as:
  - Gardening – species grown, timing, abundance.
  - Fishing, collecting and hunting on land and in rivers and the ocean – types of resources, resource abundance, when the resource is collected/hunted, who collects/hunts the resource.
  - Cultural uses of resources.
  - Frequency of consumption.
- The household survey, completed at 27 communities from all seven language groups, which collected quantitative data on subsistence activities, livestock kept, consumption of food items, important food items, and availability and income from natural resources.
- The ecosystem services (flora resources) survey, undertaken in 11 communities from the Ahia, Iare, Orokolo and Pawaia language groups, which collected information on:
  - Plant species with an identified use (e.g., domestic, hunting/fishing, cultural, firewood, construction, medicinal, food, canoe trees).
  - Location of plant resources.
  - Availability of plant resources.
  - Perceived threats to plant resources.
  - Plant resources recognized as famine foods by communities.
- The ecosystem services (fauna resources) survey, conducted at nine communities from the Ahia, Iare, Orokolo and Pawaia language groups, which obtained information on the type of fauna resources used and pattern of use.
- Opportunistic discussions with communities and observations made during the other fieldwork programs, in particular terrestrial, freshwater and marine biodiversity studies.

Information relevant to cultural ecosystem services was predominately collected from the cultural heritage key informant interview performed during the community level social baseline survey and extensively reported in Part 17 of Volume 2. This structured survey collected information on both physical sites known to communities and traditional knowledge, practices and rituals.

Information relevant to community movements and their ability to access food resources, health and education services, and work, and participate in cultural activities was obtained during the community level and household surveys. In addition, a traffic and transport study (Part 22 of Volume 2) recorded community movements observed during the freshwater and estuarine surveys (Parts 3 and 5 of Volume 2).

Regulating and supporting services information has been informed by observations, sampling and modeling undertaken for the studies into terrestrial biodiversity, geology, soils and terrain, air quality, hydrology and meteorology and groundwater. This information contributed to the assessment of the replaceability of regulating and supporting services.

Table 2 shows the categorization for each village and the associated ecological zone.

Table 2 – Categorization of Coastal and Inland Villages and Ecological Zone

Village	Language Group	Ecological Zone	Categorization
Evara	Ahia	Delta Swamps and Plains	Inland
Aivai	Iare	Delta Swamps and Plains	Inland
Aumu		Mangroves	Inland
Kaevaria		Delta Swamps and Plains	Inland
Kapai 2		Mangroves	Coastal
Maipenairu		Mangroves	Inland
Mapaio Fish Camp (settlement)		Delta Swamps and Plains	Inland
Mapaio		Delta Swamps and Plains	Inland
Akoma	Koriki	Mangroves	Inland
Ara'ava		Delta Swamps and Plains	Inland
Kairimai		Delta Swamps and Plains	Inland
Kairu'u		Mangroves	Inland
Ikinu		Mangroves	Inland
Aiere	Kaimare	Mangroves	Inland
Mariki		Mangroves	Coastal
Upaia		Mangroves	Coastal
Apiope	Maipua	Mangroves	Coastal
Poroi 1	Pawaia	Delta Swamps and Plains	Inland
Poroi 2		Middle Purari Hills	Inland
Poroi 3		Middle Purari Hills	Inland
Subu		Middle Purari Hills	Inland
Subu 2		Middle Purari Hills	Inland
Ura		Middle Purari Hills	Inland
Wabo & Wabo Station		Middle Purari Hills	Inland
Arehava 2	Orokolo	Southeast Coast	Inland
Avavu		Southeast Coast	Inland
Ere/Kilavi		Southeast Coast	Inland
Harevavo		Southeast Coast	Coastal
Hepere		Southeast Coast	Inland
Herekela		Southeast Coast	Coastal
Hururu		Southeast Coast	Coastal
Huruta		Southeast Coast	Inland
Iuku		Southeast Coast	Coastal
Kaivukavu		Southeast Coast	Coastal
Kavava		Southeast Coast	Coastal
Lariau		Southeast Coast	Coastal
Larihairu		Southeast Coast	Coastal
Marea		Southeast Coast	Coastal
Mareke		Southeast Coast	Coastal
Oru		Southeast Coast	Coastal
Paevera		Southeast Coast	Inland