Greening Industrial Estates in Singapore: Pasir Ris-Tampines Wafer-Fabrication Park

Text by Afiq Fairuz and Jason Wright
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The Masterplan

In the recent announcement of its vision as a 'City in Nature', the National Parks Board (NParks) shared plans to utilise nature-based solutions as a key element in combating climate, ecological and social resilience issues. Industrial estates have traditionally been designed as isolated and independent developments from their landscape context resulting in a segregated environment. NParks has partnered with JTC Corporation to develop a landscape masterplan for Pasir Ris-Tampines Wafer-Fabrication industrial estate (PRTPWF). The masterplan design intent is to create a new model for the industrial estate to be an integral part of its larger landscape context leading to the improvement of the quality of life for local residents and workers. NParks' aim of activating and introducing multi-functional green spaces helps to break the negative perception of the industrial estate being mono-functional and a harsh environment.

Wafer-Fabrication industrial estates, wafer fabs in short, are semiconductor plants where devices such as integrated circuits and micro-circuits are fabricated. The nature of wafer fabs manufacturing results in domineering monolithic building footprints, which limits greenery optimisation as well as creating an unattractive and lifeless visitor experience. The wafer fab manufacturing process, at the same time causes a rise in the urban heat island and carbon emission further impacting visitor experience as well as the wider community.

Situated within two heartland zones, Pasir Ris and Tampines, the concept landscape masterplan of PRTPWF emphasises nature-based solutions to enhance the resilience of the estate. With the abutting heartland zones including Sengkang, Punggol and Hougang, PRTPWF is in a strategic position to have a wider positive impact ecologically and recreationally on the north east region of Singapore (Figure 1).

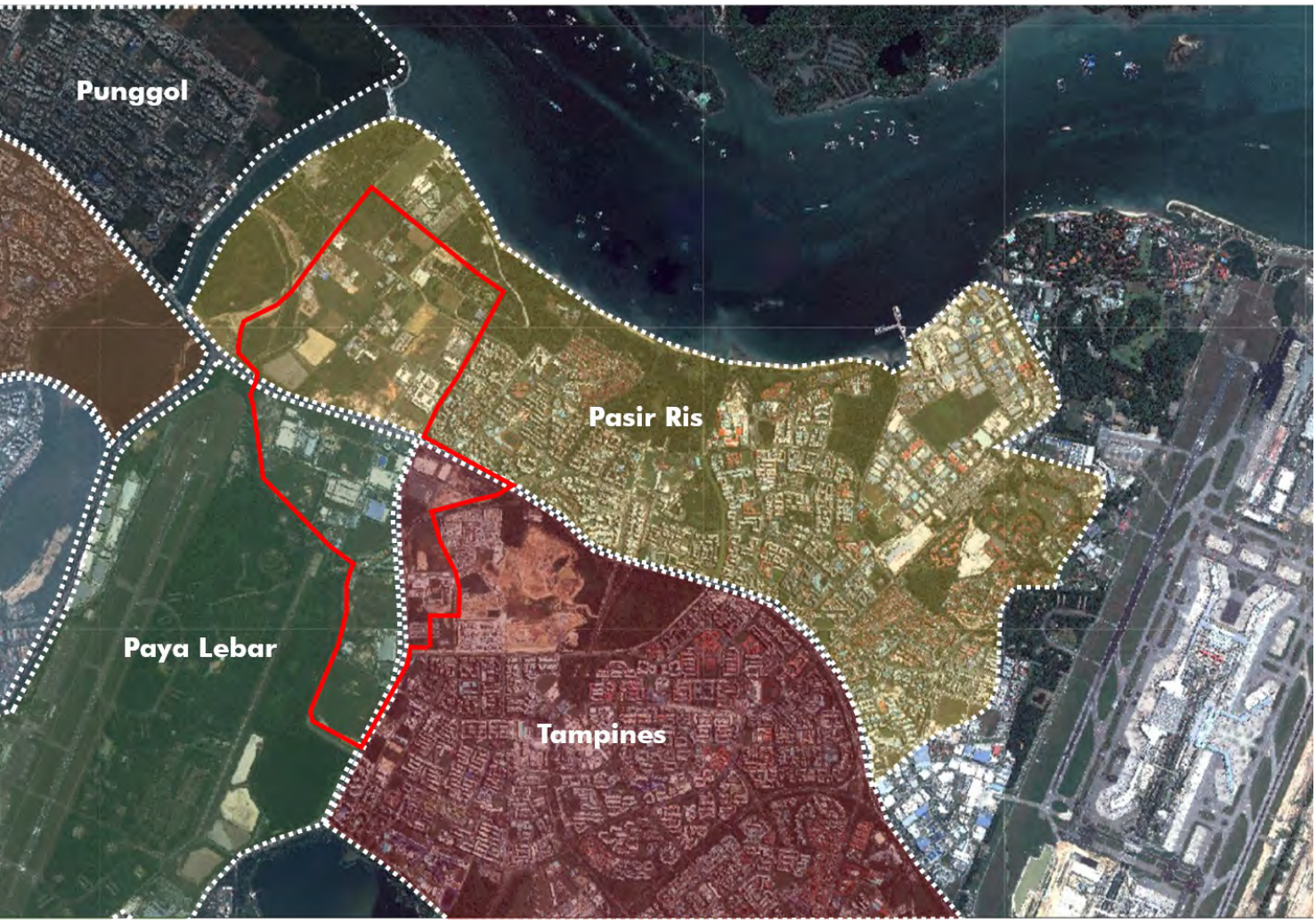
The concept landscape masterplan identifies four key issues that address the rising awareness of climate, ecological and social resilience.

1. Fragmented Habitats

Multiple parklands and waterbodies surround PRTPWF. With its massive urban industrial footprint, the wafer fabs disrupts the physical connection between the existing green and blue networks.

2. Urban Heat Island

Each of the monolithic wafer-fabs possesses a large surface area of concretised roofs resulting in a low albedo effect that increases surface temperature. Moreoever, air-handling equipment on the roofs are emitting hot air, causing an increase in ambient temperature to its environment.



1. Location of landscape masterplan of Pasir Ris-Tampines Wafer Fabrication Industrial Estate.

3. CO_2 Emission

Indirect CO_2 emissions attributed to electricity and other forms of energy purchased by the wafer fabs are contributing to Singapore's environmental impact.

4. Vibrancy & Streetscape Experience

With the large mono-functional building massing, PRTPWF is largely devoid of vibrancy, has low aesthetic attraction and poor thermal comfort. Furthermore, the lack of aesthetic, green coverage and respite areas in the estate has a negative impact on the quality of life for industrial workers and local residents.

These four key issues form the basis for the design strategies. PRTPWF aims be the first climate responsive eco-wafer fabrication estate that provides multi-functional green spaces.

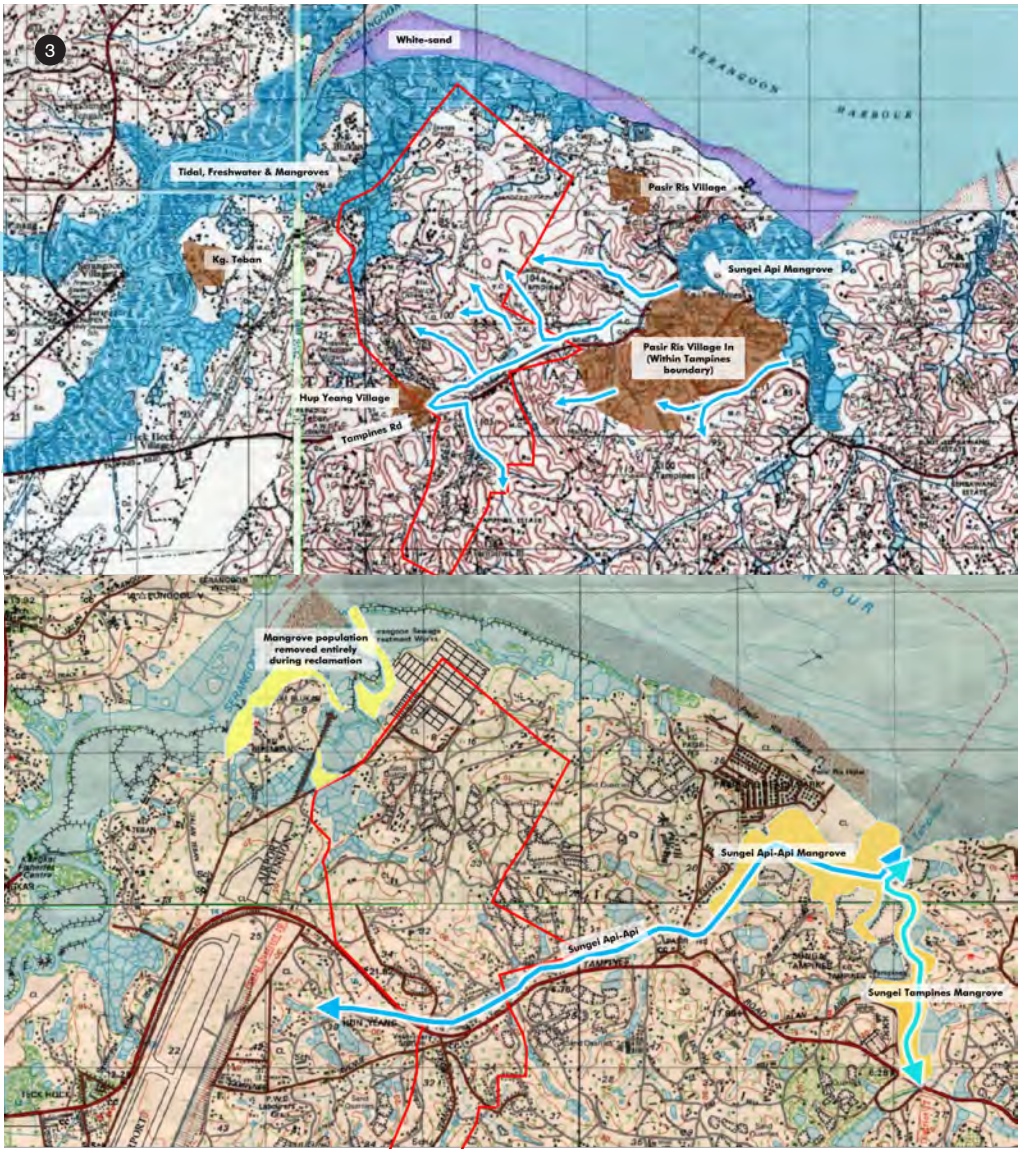
Fragmented Habitats

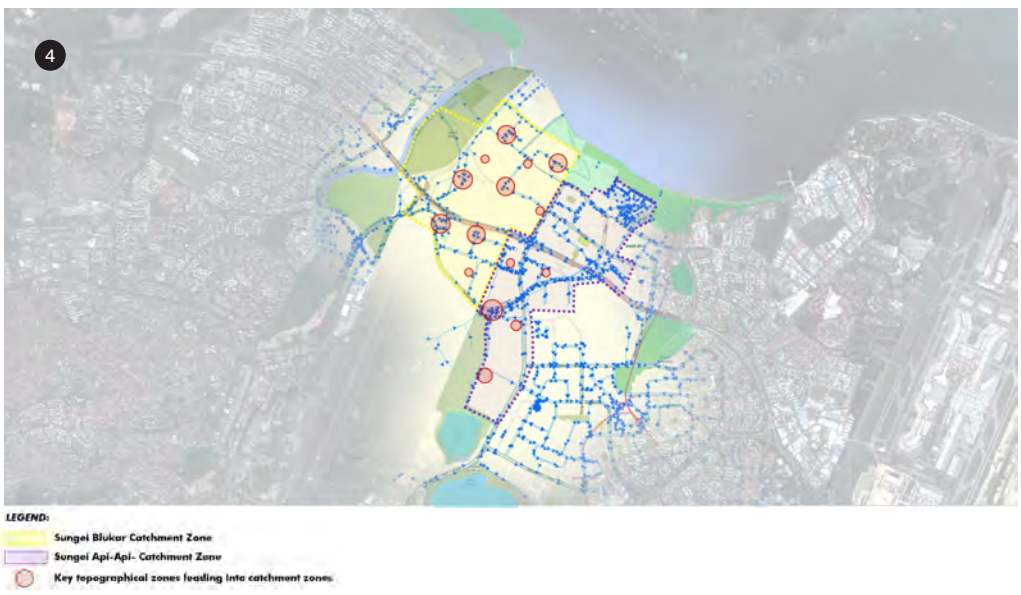
Within the masterplan boundary, the site has minimal ecological value. Mostly urban hardscapes, the industrial estate is surrounded by an extensive green and blue network, and therefore acts as a physical barrier fragmenting the habitats (Figure 2).

Drawing inspiration from the history of Pasir Ris and Tampines in the 1950s-1970s, tributaries, mangroves and freshwater ponds were commonly running through villages within the masterplan boundary. One of the key tributaries was Sungei Api-Api that still exists today but in a modified form, with the river realigned, deepened for flood mitigation and partially concretised (Figure 3). In the 1970s, the reclamation process along Pasir Ris coast removed a major population of mangroves. However, in 2001 the riverbank of mangroves at Sungei Api-Api was restored by NParks in an effort to bring back the natural heritage of the area. Planting 10,000 seedlings in a short and localised stretch along Sungei Api-Api restored the native vegetation composition of the river and has since become a significant biodiversity site with a variety of mangrove and coastal species. Pasir Ris is renowned for its popular beach at Pasir Ris Park used for a variety of coastal recreational activities. However the historical connection between the beach and upper tributaries is something that is lost today. Inspired by the past, the landscape masterplan includes restoring and re-interpreting these ecological connections as attractive waterways which simultaneously inject new recreational connectivity opportunities.

Over the decades, the tributaries and waterways have been concretised into canals and drains with only isolated stretches remaining in their natural state. NParks conducted a drainage plan study at a macro-scale to identify water catchment zones for the existing waterways which showed the site splits into two catchment zones draining into Sungei Blukar and Sungei Api-Api. The topographical study of Sungei Blukar and Sungei Api-Api catchment zones helped identify potential areas for new functional and attractive blue spaces (Figure 4).

In conjunction with the modification on the waterways in the 1950's, the vegetation was cleared to make way for developments. This led to many fragmented habitats surrounding the estate including a number of parklands. The surrounding parklands either have been isolated or have an abrupt barrier limiting connections to adjacent vegetated areas. The National Biodiversity Centre under NParks has identified an array of biodiversity species currently dwell amongst these parks and vegetated areas. With similar species found across the segregated parklands, PRTPWF seeks to provide new ecological connections between these habitats.





2. The industrial estate has potential to form ecological connections providing positive environmental benefits

3. 1950s (top) 1960-70s (bottom) map of current masterplan boundary reflects the transformation of tributaries, water bodies, villages and white sand coast.

4. Drainage plan study helped in identifying low topographical areas with the inflows and outflows of the drainage system.

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LEGEND:

- Sungei Blukar Catchment Zone
- Sungei Api-Api- Catchment Zone
- Existing Sungei Api-Api River
- JTC Proposed ABC
- NParks Proposed Naturalised Canal
- NParks Proposed Bioswales/WSUD
- NParks Proposed Detention/water ponds (subject to alignment of roads)

LEGEND:

- NParks Proposed Primary Natureway/Biodiversity Corridor
- NParks Proposed Secondary Biodiversity Corridor (subjected to road alignment)

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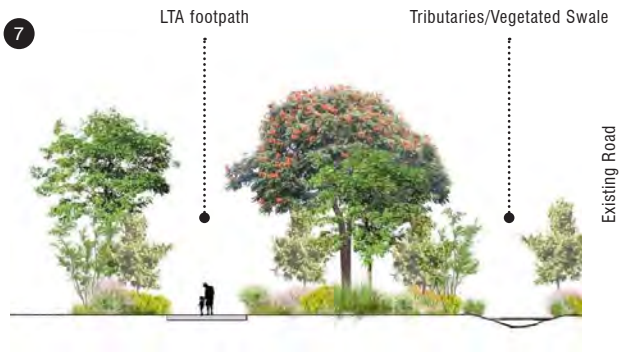

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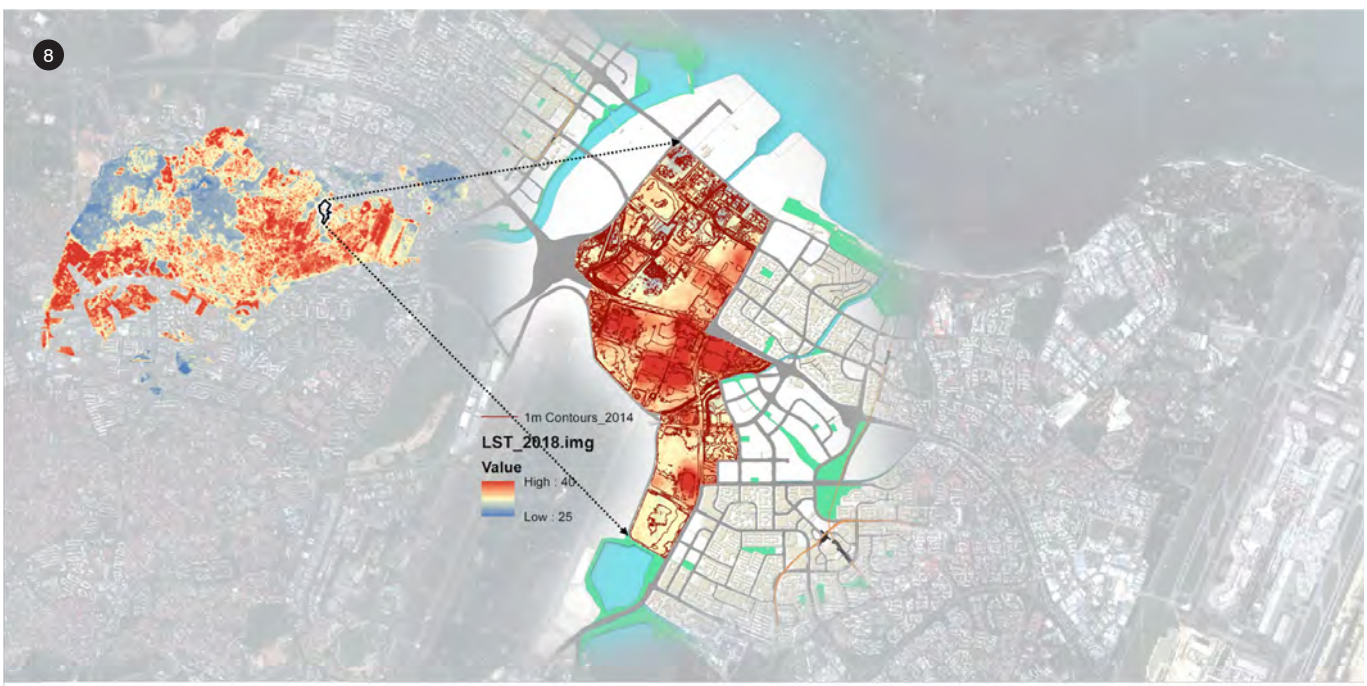

Pasir Ris Park & Sungei Api-Api

A coastal forest and mangrove habitat, inhabited by species such as oriental pied hornbills, stork-billed kingfishers, smooth coated otters and migratory grey herons.

Coney Island

A casuarina woodland habitat, inhabited by species such as smooth coated otters, migratory asian drongo-cuckoo, endangered spotted wood owl and black night crowned herons.

Lorong Halus Wetland

A wetland habitat, inhabited by species such as common kingfishers, smooth coated otters, migratory long-tailed shrikes and grey herons.

Tampines Eco-Green

A secondary rainforest and grassland habitat, inhabited by species such as white-bellied sea eagles, blue-throated bee-eaters, migratory black bazas and purple herons.

The landscape masterplan aims to overlap both the blue and green networks together to form a seamless and cohesive ecological platform. Bridging the missing links between parkland to parkland for a variety of species to migrate or inhabit, NParks proposes an intensive native planting strategy to form Nature Ways along the streets and waterways (Figure 5 & 6).

This enhanced green optimisation strategy would be supported by new interventions to the streetscapes' drainage system. The new blue network typologies incorporate the roadside drains to be converted into densely planted vegetated swales. These naturalised drains form part of the water sustainable urban design (WSUD) features that will serve to restore and reinterpret the historic tributaries of the waterways (Figure 7). A series of multiple pocket nodes featuring WSUD ponds are planned to further enhance the water quality, flood defences and evapotranspiration strategy to cool down the industrial estate. Moreover, these pocket parks serve as additional platforms for biodiversity to utilise as stepping stone while creating a new and interesting recreational space that support varied social interactions.

Urban Heat Island Effect

Through geographic information system (GIS), NParks studied the masterplan's urban heat island (UHI) index (Figure 8). The study reflected a range of high temperatures caused by the urban nature of a concretised industrial estate. In comparison with its surrounding environments comprising of residential and vegetated areas, the wafer fabs produce higher tier surface temperature values resulting in low thermal comfort. The difference in temperature between PRTPWF and its context has to do with how well the surfaces in each environment absorbs and hold heat. For this estate, wafer fabs have large paved surface which produce a low albedo effect where it reflects a small amount of incoming heat radiation while absorbing the rest. This increases the surface temperature and slowly releasing this heat increasing the ambient temperature (Figure 9).

For instance, wafer fabs' roofs are typically bare due to the technical requirements of having air-handling equipment. The air-handling equipment draw, purify and cool outside air before providing it into the wafer fabs' clean room where the fabrication of microcircuits is situated. At the same time, the equipment is emitting heat to its surrounding. This not only causes a rise in ambient temperature of

5. JTC and NParks proposal on the new blue (left) and green network (right).

6. Intensive Nature Way with tiered native planting will incorporate specific plant species that historically grew along the tributaries and waterways restoring back ecological connections between the existing parks and vegetated spaces.

7. The potential treatment of the reinterpreted tributaries along existing roads in the industrial estate.

8. Urban Heat Island in GIS of PRTPWF. Reflecting high heat index on the existing wafer fabs.

9. A diagram on existing wafer fab explaining the low albedo effect and the location of air-handling equipment.

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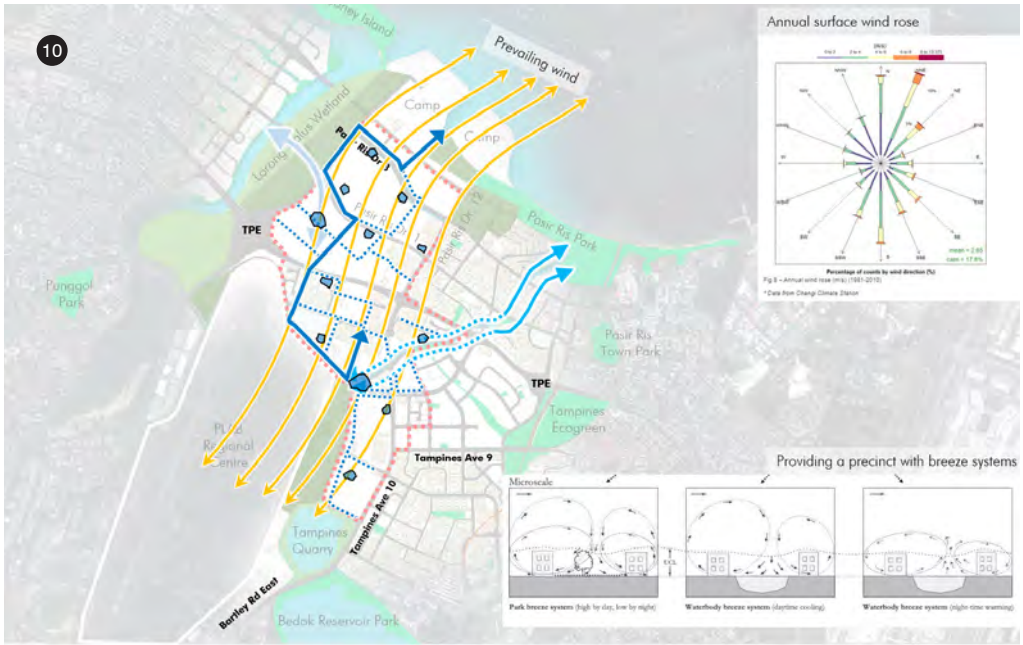

LEGEND:

- **Existing Sungei Api-Api River**
- **JTC Proposed ABC**
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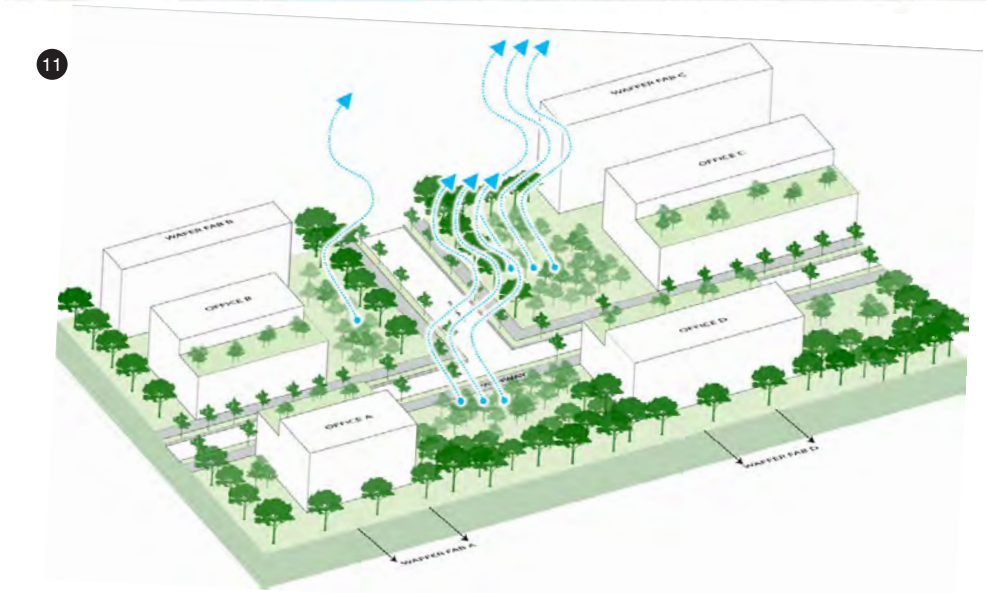

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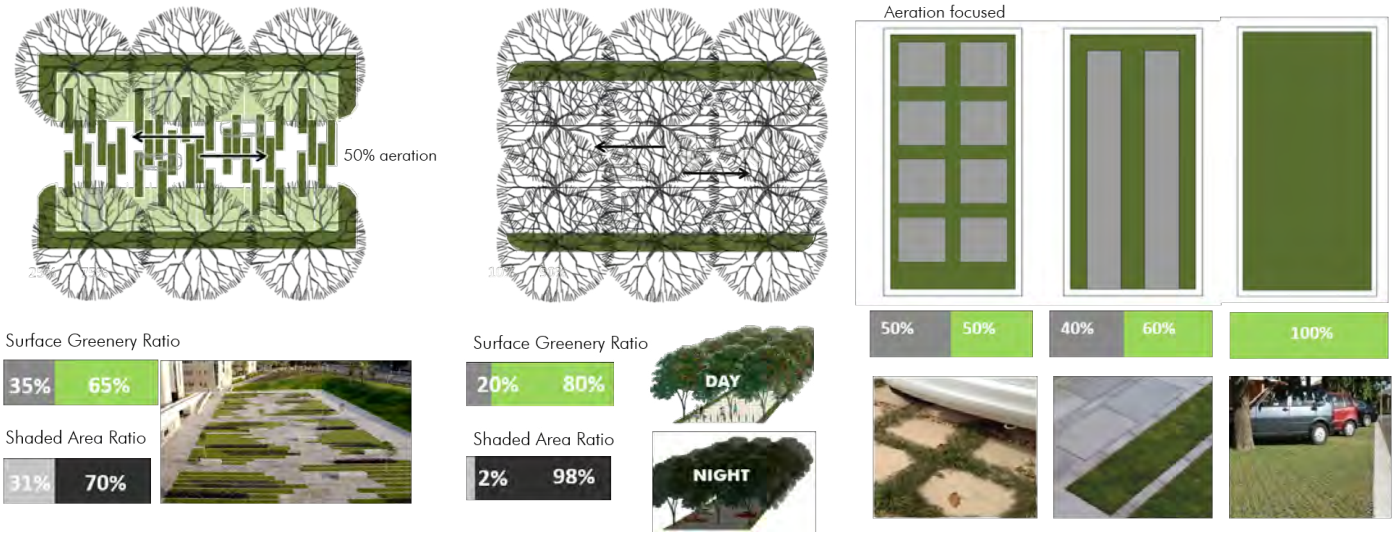

the environment, but also causes the wafer fabs to be less energy efficient in cooling the building for better thermal comfort.

NParks initiatives to combat the heat are through:

Orienting Developments

Orientation of the WSUD ponds to maximise exposure to prevailing winds.

Forested Nodes

Forested nodes within close proximity of individual wafer fabs helps increase green coverage.

Greenery Optimisation

Greenery optimisation on each individual wafer fab building through:

- Green roofs
- Vertical greenery
- Car park treatment

Orienting Developments The opportunity of utilising prevailing wind arises from the plan of developing future wafer fabs within the precinct. The study of prevailing wind is efficient and effective in providing additional natural-based solutions to help manage the UHI of PRTPWF. The prevailing wind running from NNE and SSW reflected in the annual surface wind rose (Figure 10), showcases the potential of reducing surface temperature. Creating new breeze systems, the masterplan aims to influence the future wafer fabs developments by orienting them to leverage the prevailing wind, allowing wind channels to be created in between buildings. Working hand-in-hand with the proposed blue interventions, the prevailing wind aid in circulating the evapotranspiration from the proposed waterbodies and tributaries (Figure 10).

Forested Nodes A series of forested nodal spaces are planned between the buildings to create attractive refuge spaces with the increased green coverage encouraging higher evapotranspiration levels (Figure 11). Evapotranspiration combined with shading help reduce peak ambient temperatures by 1-5°C. These strategic forest nodes located within close proximity of each wafer fab, would help mitigate the increased ambient temperature caused by the air-handling equipment on the roofs of wafer fabs creating a cooler and more comfortable environment.

Green Optimisation The vast surface areas of both facades and roofs on the existing wafer fabs buildings are not fully optimised for thermal efficiency for an estate with high energy consumption. NParks' initiative in proposing low maintenance green roofs and vertical greenery helps in thermal insulation and reducing heat absorption which can cool the immediate surrounding environment by 1.5°C and the surface temperature by 18°C (Figure 12). These greenery interventions would have additional benefits of softening the harsh monolithic structures within the estate and form part of the wider ecological connections.

Similarly, car parks alongside wafer fabs takes up large surface areas with low greenery coverage. The reduction in asphalt coverage of car parks is a priority in helping to reduce surface temperatures. There are two approaches proposed, the first is to reduce the surface area of asphalt through replacing with reinforced turf, and the second is to make ample provision for large trees to shade the asphalt (Figure 13).

10. Prevailing wind analysis flowing through the industrial precinct reflected a need to utilise the surface wind rose to the estates' advantage.

11. A network of forest nodes abutting wafer fabs.

12. An example of a green roofs and vertical greenery being implemented on an existing wafer fab.

13. Various greening typologies of car parks explored to help increase shade while reducing asphalt.

CO_2 Emission

Under the World Resources Institute's Greenhouse Gas Protocol, the Semiconductor industry falls under two scopes of emissions. Scope 1 refers to all direct emission from the activities of an organisation followed by Scope 2 being indirect emission created during the production of energy. Under Scope 1, wafer fabs emits carbon dioxide (CO_2) from fuel combustion associated with power and heat generation. Scope 2 relates to electricity consumption during the production of energy. In PRTPWF, with the ample amount of wafer fab developments within the masterplan, calls for an action to combat CO_2 emission. National Environmental Agency (NEA) had reflected that under the United Nations Framework Convention on Climate Change PWFNCFS 2010, initiatives have been carried out to combat energy consumption. The introduction of Trigeneration facilities in Singapore is an integrated energy efficient system that produces three types of utilities – for instance electricity, steam and chilled water.

With existing initiatives being implemented and tested to raise awareness on energy efficiency within the semiconductor industry, NParks' nature-based approach will aid in amplifying this initiative by further reducing CO_2 emission through greenery.

The strategy of proposing a network of forested nodes will be developed as a platform for dense plantation planting that focuses on carbon sequestration. Planting palettes such as back-mangrove species along the waterways and large woody trees can help to sequester more CO_2. Mangroves can store more than three times of carbon as compared to terrestrial forests. Our mangroves only occupy less than 1% of Singapore's land and the carbon stored is equivalent to about 3.7% of Singapore's total CO_2 emissions in 2010. An example of the effectiveness to reduce carbon through greenery would be, by planting 50,000 trees, this may lead to an increase in carbon stock by 1,000-3,000 tonnes of carbon in 10 years. Equivalent to 4,000-11,000 tonnes of CO_2 sequestered. There are other ecosystem services that these planted trees will also provide.

Streetscape Experience & Vibrancy

Alongside JTCs' vision to redevelop industrial areas into an attractive and sustainable environment, the landscape masterplan assists in enhancing the estate to attract local residents and retain talents within the wafer fab industry. An array of initiatives that injects life into PRPTWF through enhancing its streetscape experience and vibrancy of its proposed destinations:

1. Urban Design Guidelines

Enhancing the development guidelines for wafer fabs to attain more flexibility and opportunities for greenery optimisation.

2. Commuting & Recreational Network

A well-connected network for all users to enjoy new destinations.

3. Strings of Connected Pocket Parks

Programming forested nodes for diverse attractions throughout the estate.

14. Existing monolithic buildings dominating in scale.

15. Existing condition of how the wafer fab interfaces with the streetscape.

16. Iterative diagram showing the various type of complex architecture forms of wafer fab office buildings facing the frontage of streetscapes.

17. The proposed section reflecting the unique urban design guideline featuring the new typologies applied to streetscapes.

> The concept landscape masterplan of PRTPWF emphasises nature-based solutions to enhance the resilience of the estate.

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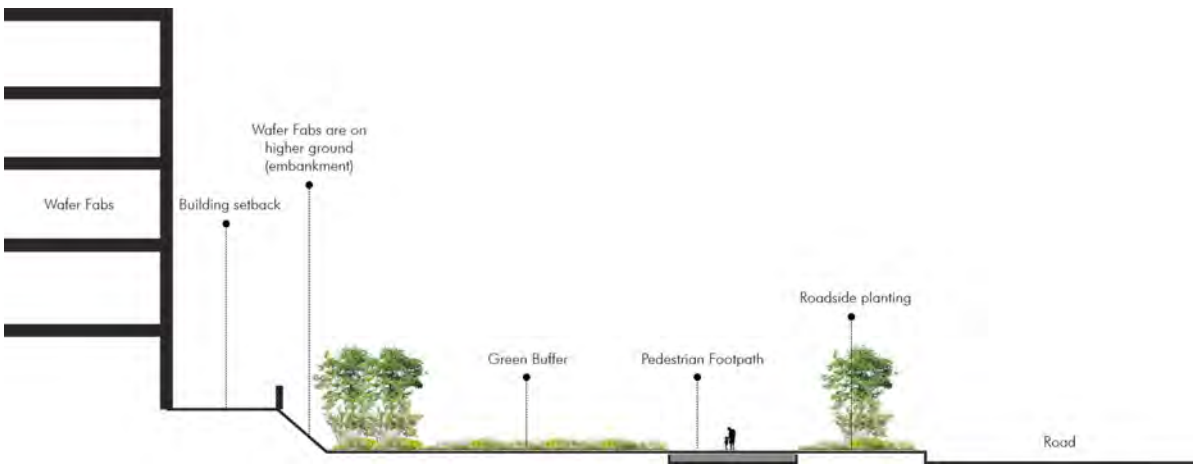

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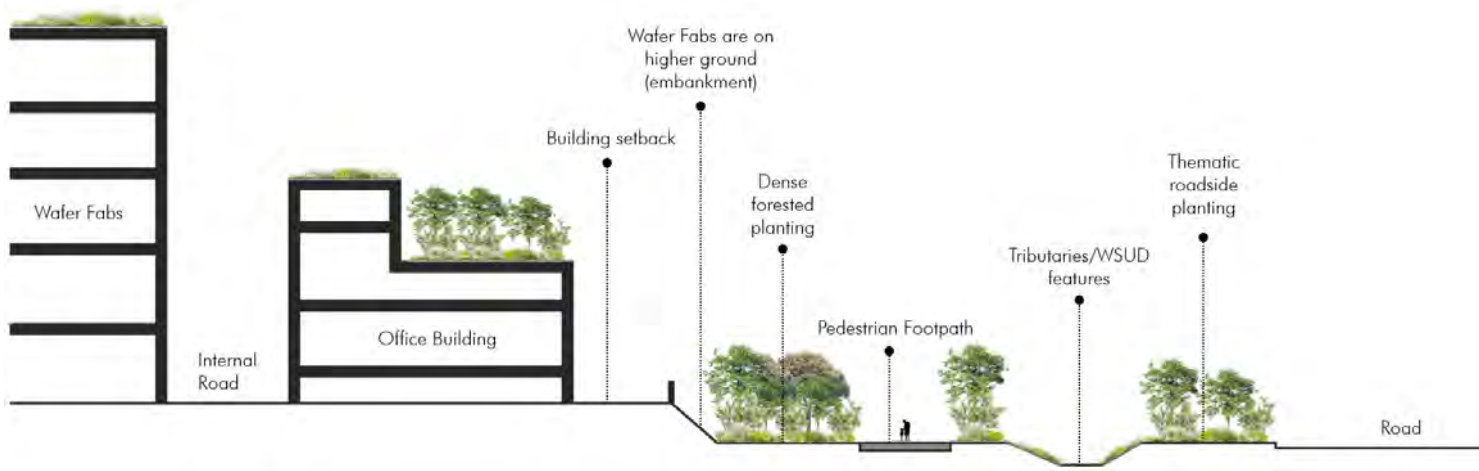

> The landscape masterplan complements identified attractions by providing a well-connected Park Connecter Network, which serves as a recreational and biodiversity corridor within PRTPWF.

Urban Design Guidelines

There are opportunities to enhance the urban design guidelines that allows the establishment of vertical and skyrise greenery. The architecture of wafer fabs are limited in their flexibility therefore modifications to the wafer fabs would be a challenge as it affects efficiency in production. However, associated with the wafer fab buildings are often office buildings which do allow for more flexibility in the design with the potential to introduce new greenery interventions. Currently, wafer fab buildings with their large monolithic scale are interfacing directly with the existing streetscapes, resulting in a lifeless pedestrian experience (Figure 15).

Proposals will be explored for a new configuration where office buildings will be abutting and fronting the streetscapes with the wafer fabs and its monolithic scale hidden behind. The office buildings will be encouraged to have architectural designs that allows for creative greenery spaces and more vibrant facades. For example, green fingers into the building that increases both green coverage and recreational spaces while having a terraced form that allows for accessible green roofs (Figure 16).

This new office building typology integrated with greenery would not only help in creating more human scale pedestrian experience but also, to create a more vibrant streetscape experience (Figure 17).

Enhancing Commuting & Recreational Network

JTC identified existing key activity nodes and strategically planned future activity nodes to activate the estate as a lifestyle destination (Figure 18). The landscape masterplan complements these identified attractions by providing a well-connected Park Connecter Network (PCN). Injecting PCN and Nature Ways to serve as a recreational and biodiversity corridor within PRTPWF (Figure 19) allows for users to easily access both workplaces and recreational areas with an array of attractive routes. Planting schemes will be curated with a variety of native species, forms and colours that will help distinguish identities of different streetscapes and create a better wayfinding experience.

18. Existing and proposed network of nodes (Image: JTC & National Parks Board)

19. Existing and proposed connectivity mapping within PRTPWF (Image: National Parks Board & JTC)

20. Proposed pocket park network within 400m walkable distance (Image: National Parks Board & JTC)

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Existing Points of Interests Existing Activity Node JTC Proposed Activity Node

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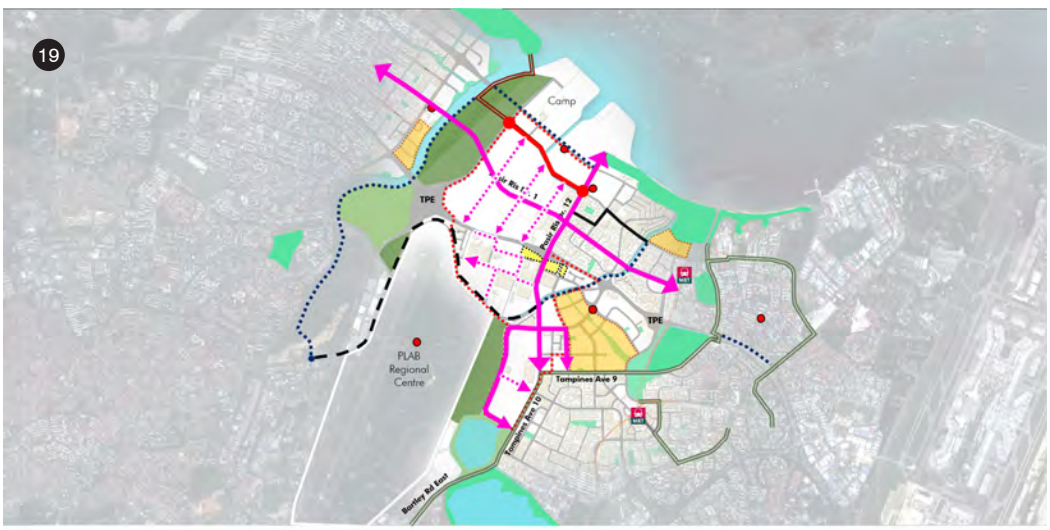

Upcoming MRT
Upcoming Residential Estates
Ikea/Courts/Tampines Furniture Hub
Existing RIR
Existing PCN
Existing CPN
Safeguarded PC
Safeguarded CPN
NParks proposed PCN
NParks proposed secondary natureway
JTC Proposed Transit Corridor

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> “The use of nature-based solutions within the landscape masterplan sets a model for wafer fab industries to adopt to become climate resilient while enhancing ecological and social connections

Strings of Connected Pocket Parks

Pocket parks are planned within 400m from major transport nodes and activity nodes. The pocket parks will be designed to create accessible green spaces for respite and recreation which overlap with the locations of the forested nodes (Figure 20). They provide opportunities to create therapeutic landscapes easily available for workers for daily respite from the factories and offices. Furthermore, the pocket parks could be utilised as platforms for events and community activities facilitating worker interaction and integrating the estate into the wider residential community.

Conclusion

NParks’ vision as a City in Nature will see NParks and JTC’s landscape masterplan for PRTPWF focusing on increased efforts in habitat restoration, mitigatng UHI and CO_2 emissions, and enhancing the streetscape experience all through nature-based solutions (Figure 21). The use of nature-based solutions within the landscape masterplan would set a future model for wafer fab industries to adopt to become climate resilient while enhancing ecological and social connections to the wider context (Figure 22).

21. The enhanced streetscape offering a rejuvenating experience.

22. The new wafer fab industrial precinct of Pasir Ris Tampines Wafer Fab Park featuring an existing and a newly developed wafer fab buildings accompanied with new green and blue destinations.