RE-IMAGINING THE URBAN DEVELOPMENT OF WESTERN SYDNEY: THE CASE STUDY OF ORAN PARK

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Abstract. This paper addresses the challenges of rapid urban expansion in Western Sydney, Australia, using the suburb of Oran Park as a case study. With the region's population projected to more than double by 2041, and an expected influx of an additional 400,000 people by 2030, there is a pressing need for sustainable and environmentally responsive urban development. Current approaches have prioritised space utilisation over environmental and social considerations, leading to homogeneity and poor urban quality. In response to these challenges, this study proposes a four-stage generative model for Oran Park, emphasising environmental restoration, agricultural integration, and housing diversification. This model aims to balance economic growth with environmental sustainability, contrasting with the density-focused development prevalent in the area. By implementing multi-objective optimisation, this research presents an algorithm-driven approach to urban planning, catering to the diverse needs of the expanding population.

Keywords. Western Sydney, Oran Park, Sequential Simulations, Evolutionary Algorithm, Computational Design, Urban Growth, Housing Development

1. Introduction

Sydney, Australia is currently experiencing rapid growth in urban settlement, resulting in significant demand for housing in the most populous and urbanised state within Australia, New South Wales (Farid Uddin & Piracha, 2023). Coupled with a significantly increasing housing market, and limited space within existing infrastructure in the city, Sydney's urban sprawl has expanded rapidly towards the western part of the state, known as the Greater Western Sydney region (Lawton & Morrison, 2022). This expansion presents both opportunities and challenges. On the one hand, it offers a chance for economic growth and the development of new communities; on the other hand, it underscores the pressing need for strategic urban planning to ensure that growth is sustainable, equitable, and integrates well

ACCELERATED DESIGN, Proceedings of the 29th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2024, Volume 1, 353-362. © 2024 and published by the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA), Hong Kong.

with the existing urban fabric through environmental, historic and future climate considerations.

The rapid urban expansion in Western Sydney, a region projected to see its population double from 2.4 million in 2016 to 4.1 million by 2041, presents critical challenges in urban planning and environmental sustainability (DPIE, 2019). This phenomenon is not confined to temperature changes. Western Sydney, Australia’s third-largest economy and a rapidly growing centre for population and employment, faces challenges beyond just urban heat (Forster 2006). The Australian Government's Centre for Population predicts an influx of 400,000 people into Western Parkland City's eight local government areas (LGAs) by 2030 (DPIE, 2019). By 2031, over half of Sydney's population will reside in Western Sydney (Morrison et al. 2022). Historic precedents of rapid urban growth triggered by population demands showcase repetitive housing developments that prioritise the use of space over all else and do not enable the development of supportive infrastructure such as schools, open spaces and community facilities (Minns, 2023). This results in a complete disregard for the quality of the urban setting, its relationship to the environment surrounding it, and the community that it supports (Minns, 2023). Such practices underscore the urgency of sustainable urban planning despite the temporal stresses on urban growth.

2. Background and Context

2.1 ENVIRONMENTAL AND GEOGRAPHIC RESPONSES OF NEW URBAN DEVELOPMENTS

According to the Department of Environment and Climate Change (2008), the Sydney region, including Western Sydney, is experiencing significant climate change impacts. The Greater Sydney Region Plan, anticipates a population surge to 5.3 million by 2031, necessitating an additional 640,000 homes and 500,000 jobs (Department of Planning NSW, 2005). Western Sydney's exposure is heightened due to its lack of cooling sea breezes, unlike Sydney's eastern coastal suburbs. A University of Technology Sydney research analysis revealed that temperatures in Western Sydney are rising at over twice the rate of coastal suburbs or the global warming average (Lewins, 2023). This exacerbates the urban heat island effect, where urban development and dark-coloured surfaces increase local temperatures, impacting health and infrastructure (Lewins, 2023).

Addressing the challenges of cooling urban environments demands a comprehensive approach that extends beyond the introduction of tree canopy. It involves rethinking suburb planning, valuing open vegetated spaces, reducing car dependency, and reconsidering dwelling sizes and construction materials (Morrison et al. 2022). Water harvesting and reuse also play a crucial role in supporting plant growth for cooling. However, current master planning practices have often led to a lack of green spaces, contributing to urban overheating (Morrison et al. 2022).

2.2 HOUSING DEVELOPMENTS

The prevailing urban development strategy in Western Sydney has primarily revolved around the expansion of broadacre housing estates, often neglecting the essential provision of community facilities and services (Johnson, 2016). This emphasis on expansion raises concerns about the preservation of an adequate 'quality of place,' a concept frequently underscored in global city discourse (Mee, 2010). However, there is a increasing shift in the political landscape, with various authorities pushing for a redirection of focus towards higher-density developments, particularly in areas with high amenities already established.

The New South Wales Premier Chris Minns is pushing for the construction of 75,000 homes annually, doubling the Department of Planning's 2022 forecast, to address the state's housing crisis (Wikramanayake, 2023). The proposed plan includes the establishment of high-density towers near train stations, complemented by detached housing initiatives. Minns envisions the annual creation of 10,000 to 20,000 homes through six-story apartment complexes. However, this ambitious plan encounters challenges, such as the approval of only 6,000 homes in such complexes by September, resident resistance to medium-density housing, and the need for the construction industry to adapt (Wikramanayake, 2023). Additionally, the government plans to meet housing demands by expanding, demolishing, or redeveloping 50,000 existing apartment complexes built before 2000 (Wikramanayake, 2023).

2.3 CASE STUDY: ORAN PARK

As Western Sydney evolves, it becomes clear that the region is no longer a homogeneous landscape representing the ‘Australian Dream’. Instead, it is a microcosm of global processes, marked by social polarisation and tensions (Morgan 2005). These changes in the region's demography and landscape highlight the ongoing role of Western Sydney as a suburban home but also signal the need for a more nuanced understanding and approach to urban planning in this dynamically evolving area. The Western Sydney region, already witnessing significant growth as evidenced by the plethora of residential developments designed and built in the last decade, is grappling with the consequences of neglecting climate and land considerations in its urban design. Oran Park, aiming to accommodate up to 45,000 occupants, exemplifies this issue with its repetitive housing patterns and lack of basic urban infrastructure, creating a car-dependent suburb with little regard for pedestrian needs or climate adaptability (Morrison et al. 2022).

An alternative urban strategy for Oran Park, and similar estates in Western Sydney, is vital for the sustainable growth of urban development in the region. Through the utilisation of a multi-objective optimisation model, the research presents a proposal that reimagines the urban growth of Oran Park the considers the site's environmental and sociodemographic factors. The first stage of this model focuses on restoring the natural topography and leveraging existing water bodies, addressing the issue of Oran Park being built on flood-zoned farmland, which has caused unintended flooding and toxic runoff in adjacent areas. The second stage involves creating agricultural zones for local workers, promoting medium-scale farming and self-sufficiency. The third stage proposes an irrigation system linked with aquaponic systems for agriculture and floodwater management. Finally, the fourth stage suggests increasing population density with diverse building typologies, supporting new commercial infrastructures like hospitals and schools. These stages aim to harmonise Oran Park's present and future needs, offering a stark contrast to current urban practices in Western Sydney and showcasing the potential of computational models and algorithmic processes in urban planning.

3. Experiment Setup

The application of multi-objective evolutionary algorithms (MOEAs) in design, specifically urban design, has gained momentum over the last decade. The adoption of MOEAs to solve complex design problems has enabled designers to address one of the primary challenges for the design of urban spaces: the ability to simultaneously address multiple conflicting design objectives without necessitating trade-off decisions between the design goals. In this context, the presented research employs the NSGA-2 algorithm (Deb et al., 2000). situated within the Grasshopper plugin Wallacei (Makki et al., 2018).

3.1 DESIGN PROBLEM

The proposed model utilises Oran Park as a case study, proposing a hypothetical scenario in which the presented experiment is situated on Oran Park’s site before its current development. This flood-prone site in its pre-existing condition sees low-lying terrain and two water catchments connected to neighbouring agricultural properties. The first step of the process remodels this topographical condition and maps the water run-off paths on site through particle simulation (using Kangaroo 3D). The evolutionary algorithm selects one run-off line and extends it to the site boundaries, optimising to connect both water catchments at a maximum length (Figure 1A). This initial selection by the algorithm of the primary irrigation line forms the foundation of the proposed model, stipulating the axis on which the urban grid is situated.

Two sets of boundary lines ran parallel to the selected run-off path and were allocated as the shared agricultural corridor. The interior corridor was divided into lot sizes of either 2500m^2, 5000m^2 or 7500m^2. Exterior lots of 5000m^2 + were allocated as communal agricultural space and lots of 2500m^2 were for single-detached residential (SDR) properties (Figure 1B). Building footprints of 400m^2 were placed on SDR lots and extruded to either single or double storey heights based on their proximity to the communal agricultural spaces (Figure 1C). Exterior lots that fell into the water catchment boundary were elevated on structural supports above the water. Houses closer to these spaces were smaller in height, and those further were taller. This height management continued across the entire urban patch in order to ensure minimal solar obstruction on agricultural spaces and neighbouring buildings.

The following stage in the urban proposal introduced an irrigation system that follows the central run-off line, connecting every exterior lot to a system linking the water catchments at either end of the site (Figure 1D). A 40mx40m grid was generated on the same axis as the selected line and divided into four quadrants of varying size (Figure 1E). Cells with an area larger than 350m^2 were allocated as low-rise Residential Flat Buildings (RFB), offset 6m deep and split to create internal courtyards (Figure 1F). Every RFB building was extruded to a single-storey height, creating a mix of ground or level one communal gardens. A second set of extrusions were made above the RFB blocks with level counts informed by their proximity to the nearest communal agricultural space in the central corridor (Figure 1G). The remaining cells that were between 350m^2 and 300m^2 were allocated as high-rise RFB with a storey height ranging from 6-14 according to the same height management proximities as SDR and low-rise RFB. The remaining cells smaller than 300m^2 were offset by 2m to form a joined region allocated as communal agricultural grounds in the higher density zone of the urban plan (Figure 1H).

The remaining space was divided into a 20mx20m grid along the consistent axis. A cull pattern was used to remove 50% of the cells which were then allocated as multi-use buildings. Any connected buildings were joined into a single cell and extruded between a 2-5 storey height range according to height management proximities (Figure 1I). The 6m gap between buildings on the ground plane allowed space for a road network that would run through the high-density zone and along the boundaries of the external agricultural corridor (Figure 1K). To address the higher plain of the site, a set of pedestrian platforms and paths were combined and elevated at 1st storey height (Figure 1J). These paths all stem from a central path following the selected run-off line to form the tradeline that connects urban zones across the agriculture corridor and water bodies. Where the tradeline bridges the water bodies, a minimum of two aquaponic towers were placed, generating an enhanced irrigation loop that feeds the agricultural network across the site (Figure 1L).

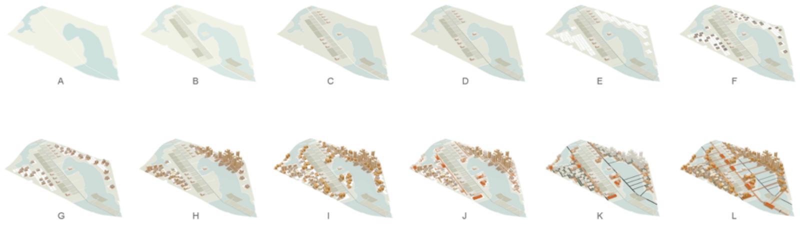
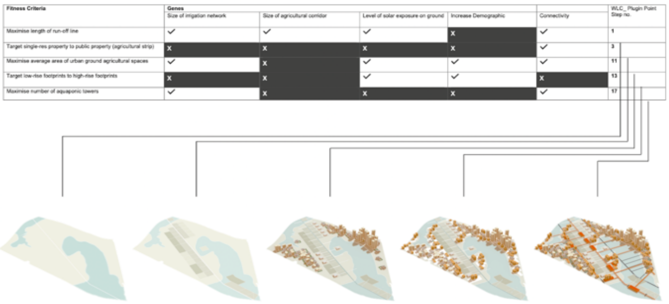


Fig. 1 (Construction of Phenotype – 1A-L)

3.2 FITNESS OBJECTIVES

The design model presented in the previous sections identifies the design variables that the algorithm modified to improve the fitness of each design solution. As such, the fitness functions (or design goals) that the algorithm aims to optimise for are the following five functions: The first is to maximise the length of the run off line to ensure it encompasses the entire site; the second sets a target ratio between single residential dwellings to agricultural land ; the third maximises the area of agricultural spaces; the fourth targets a ratio between low-rise and high-rise typologies; and the final function maximises the number of aquaponic tower to allow for maximum water catchment. The design matrix (Figure 2) outlines the relationship between the five fitness objectives, the design variables (explained in the previous section) and urban form. Visualising the design problem through this matrix allows for a more efficient 'debugging' of the design problem as it directly identifies the impact of each gene on each fitness objective and highlights imbalances that may be built into the developed model. This helps weigh phenotypic indicators in the selection process.



Fitness Criteria	**Genes**					WLC_ Plugin Point Step no.
	Size of irrigation network	Size of agricultural corridor	Level of solar exposure on ground	Increase Demographic	Connectivity	
Maximise length of run-off line	✓	✓	✓	x	✓	1
Target single-res property to public property (agricultural strip)	x	x	x	x	✓	3
Maximise average area of urban ground agricultural spaces	✓	x	✓	✓	✓	11
Target low-rise footprints to high-rise footprints	x	x	✓	✓	x	13
Maximise number of aquaponic towers	✓	x	x	x	✓	17

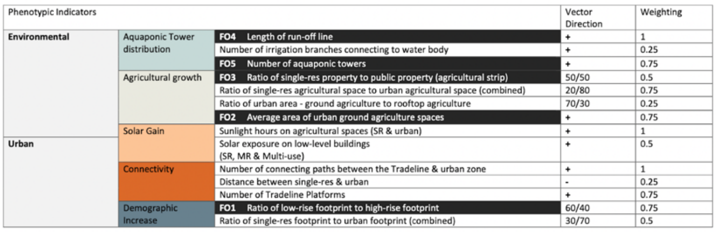
Fig. 2 (Design Matrix)

4. Experiment Results and Selection Process

4.1 SELECTION PROCESS

The algorithm evolved a total of 4000 design solutions with a simulation runtime of 39 hrs and 19 minutes. Identifying the best evolved solution in the algorithm requires a collateral analysis of the Pareto Front using additional urban metrics for the purpose of filtration (Showkatbakhsh & Makki, 2022). The algorithm generated 40 Pareto Front solutions, which were then clustered using a K-means clustering algorithm with a K-value of 16. Each cluster centre was selected to represent its respective cluster for further analysis.

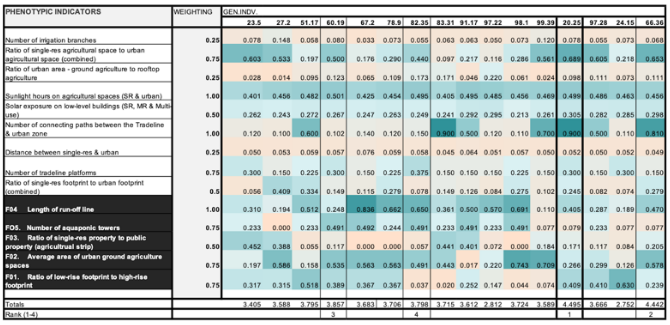
A total of three filtration steps were implemented for selecting the top design solution. As part of the first and second filtration steps, the indicators used for analysis were prioritised through the allocation of weighting, thus varying the impact of each indicator on the analysis results; while the third step allocated equal weighting to the analysis metrics primarily due to their small number, which required less differentiation. The first filtration step prioritised the two highest-weighing fitness objectives alongside the highest mode values of urban metrics. These fell under two principal categories; Environmental (FO4 Length of run-off line) and Urban (FO1 Ratio of low-rise footprint to high-rise footprint) (Figure 3).



Phenotypic Indicators			Vector Direction	Weighting
Environmental	Aquaponic Tower distribution	**FO4 Length of run-off line**	+	1
		Number of irrigation branches connecting to water body	+	0.25
		FO5 Number of aquaponic towers	+	0.75
	Agricultural growth	**FO3 Ratio of single-res property to public property (agricultural strip)**	50/50	0.5
		Ratio of single-res agricultural space to urban agricultural space (combined)	20/80	0.75
		Ratio of urban area - ground agriculture to rooftop agriculture	70/30	0.25
		FO2 Average area of urban ground agriculture spaces	+	0.75
	Solar Gain	Sunlight hours on agricultural spaces (SR & urban)	+	1
Urban		Solar exposure on low-level buildings (SR, MR & Multi-use)	+	0.5
	Connectivity	Number of connecting paths between the Tradeline & urban zone	+	1
		Distance between single-res & urban	-	0.25
		Number of Tradeline Platforms	+	0.75
	Demographic Increase	**FO1 Ratio of low-rise footprint to high-rise footprint**	60/40	0.75
		Ratio of single-res footprint to urban footprint (combined)	30/70	0.5

Fig. 3 (Phenotypic Indicators)

The second filtration step took scores ranking in the top 25% of the ranking matrix (Figure 4) and assessed them against a series of manual calculations. The matrix used a colour scheme to score solutions based on calculations specified in the urban metrics. The four Pareto Fronts selected were further assessed on accessibility, connectivity, solar gain, and demographic distribution.



PHENOTYPIC INDICATORS	WEIGHTING	GEN.INDV.															
		23.5	**27.2**	**51.17**	**60.19**	**67.2**	**78.9**	**82.35**	**83.31**	**91.17**	**97.22**	**98.1**	**99.39**	**20.25**	**97.28**	**24.15**	**66.36**
Number of irrigation branches	**0.25**	0.078	0.148	0.058	0.080	0.033	0.073	0.055	0.063	0.063	0.050	0.073	0.120	0.078	0.055	0.073	0.068
Ratio of single-res agricultural space to urban agricultural space (combined)	**0.75**	0.603	0.533	0.197	0.500	0.176	0.290	0.440	0.097	0.217	0.116	0.286	0.561	0.689	0.605	0.218	0.653
Ratio of urban area - ground agriculture to rooftop agriculture	**0.25**	0.028	0.014	0.095	0.123	0.065	0.109	0.173	0.171	0.046	0.220	0.061	0.024	0.098	0.111	0.073	0.111
Sunlight hours on agricultural spaces (SR & urban)	**1.00**	0.401	0.456	0.482	0.501	0.425	0.454	0.495	0.405	0.495	0.485	0.456	0.469	0.499	0.486	0.463	0.456
Solar exposure on low-level buildings (SR, MR & Multi-use)	**0.50**	0.262	0.243	0.272	0.267	0.247	0.263	0.249	0.241	0.292	0.295	0.213	0.261	0.305	0.282	0.285	0.298
Number of connecting paths between the Tradeline & urban zone	**1.00**	0.120	0.100	0.600	0.102	0.140	0.120	0.150	0.900	0.500	0.120	0.110	0.700	0.900	0.500	0.110	0.810
Distance between single-res & urban	**0.25**	0.050	0.053	0.059	0.057	0.076	0.059	0.058	0.045	0.064	0.051	0.057	0.050	0.052	0.050	0.052	0.049
Number of tradeline platforms	**0.75**	0.300	0.150	0.225	0.300	0.150	0.225	0.375	0.150	0.150	0.150	0.225	0.150	0.300	0.150	0.300	0.150
Ratio of single-res footprint to urban footprint (combined)	**0.5**	0.056	0.409	0.334	0.149	0.115	0.279	0.078	0.149	0.126	0.084	0.275	0.102	0.245	0.082	0.074	0.279
F04 Length of run-off line	**1.00**	0.310	0.194	0.512	0.248	0.836	0.662	0.650	0.361	0.500	0.570	0.691	0.110	0.405	0.287	0.189	0.470
FO5. Number of aquaponic towers	**0.75**	0.233	0.000	0.233	0.491	0.492	0.244	0.491	0.233	0.491	0.233	0.491	0.077	0.079	0.233	0.077	0.077
F03. Ratio of single-res property to public property (agricultrual strip)	**0.50**	0.452	0.388	0.055	0.117	0.000	0.000	0.057	0.441	0.401	0.072	0.000	0.184	0.171	0.117	0.084	0.205
F02. Average area of urban ground agriculture spaces	**0.75**	0.197	0.586	0.158	0.535	0.563	0.563	0.491	0.443	0.017	0.220	0.743	0.709	0.266	0.299	0.126	0.578
F01. Ratio of low-rise footprint to high-rise footprint	**0.75**	0.317	0.315	0.518	0.389	0.367	0.367	0.037	0.020	0.252	0.147	0.044	0.074	0.409	0.410	0.630	0.239
Totals		3.405	3.588	3.795	3.857	3.683	3.706	3.798	3.715	3.612	2.812	3.724	3.589	4.495	3.666	2.752	4.442
Rank (1-4)					3			4						1			2

Fig. 4 (Scoring of Phenotypic Indicators – Ranking Matrix)

The goal for accessibility was to maximise access to the urban agriculture zones from the RFB blocks, calculating the number of paths generated between the two under a 20m radius (Figure 5A). The intention is to activate hubs within the superblock with community functions of engagement, gathering and collaboration (e.g. community gardens). Similarly, connectivity aimed to maximise site coverage while minimising the average length of a path before it turns, calculating average path lengths against the total pathway area (Figure 5B). The current pedestrian network in Oran Park is partly disconnected and unsafe as it is secondary to that of the vehicle. Optimising pathway connectivity prioritises the pedestrian, generating higher use (coverage) and comfortable access (length). With a heavy emphasis on supporting agricultural networks across site, it was important to maximise solar access on both the ground plane and rooftops. This was done by calculating the percentage of solar hits above 4 (out of 6), prioritising the agricultural corridor (Figure 5C). The demographic distribution analysis was assessed based on two target ratios; (a) 50/50 between Multi-use and Residential typologies and (b) Residential balance ratio of 10% SR, 20% MR (2 person) and 20% MR (4 person) (Figure 5D). Engaging a balanced variety of building typologies allows for a wider range in user demographics. This in turn supports the growth of socio-economic systems within Oran Park and its neighbours.

The third and final filtration step focussed on agricultural distribution and potential across the 5 land typologies; agricultural (private), agricultural (communal), urban ground (communal), urban rooftop (private), urban rooftop (communal) and waterbodies. A calculator was made using a list of fruits and vegetables typically grown in the Camden Council region, as well as poultry and aquaponics. These items were assessed on the estimated growth per acre or square metre of land, alongside rooftop options and sunlight needs (hours and shade tolerances). This calculator was then used to quantify the optimal target ratios for area per land typology; (a) 60/40 between Agricultural Zones and Urban Zones and (b) Zone balance ratio of Agricultural.P 15%, Agricultural.C 45%, Urban Ground 20%, Rooftop.P 5%, Rooftop.C 15% (Figure 5).

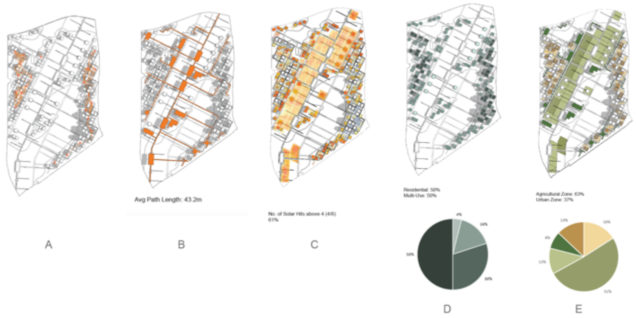


Fig. 5 (Analysis Diagrams – 5A-E)

5. The Selected Solution

Following the three-step filtration process, Generation 20, Individual 25 was selected as the most successful solution from this simulation. To further investigate and understand the relationships between the varying typologies in the selected solution, two focal points were selected and designed at a closer scale. These focal points highlight the two significant thresholds of the site; urban zone to agriculture corridor and tradeline to waterbody. The urban to agriculture threshold includes multiples of each of the four building typologies (Figure 6 (left)), highlighting their unique relationships with each other and the surrounding site. Implementation of communal platforms and garden spaces aims to consolidate these distinctive building typologies, allowing them to not only exist within close proximity but establish a high level of connectivity and user engagement. In the second focal point, the tradeline to waterbody threshold includes multiples of two building typologies connected to the trade market and aquaponic towers (Figure 6 (right)). This focal point captures the central line of the agriculture corridor and irrigation network, highlighting how the communal platforms and garden spaces land in this zone differently to the urban zone. Identifying the relationship between water-specific typologies and the agriculture corridor through manual design gave additional insight into how spatial interactions surrounding the tradeline would function.

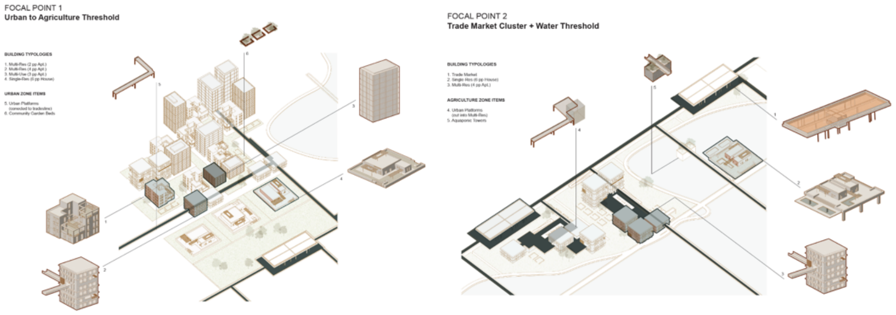


Fig.6: (left) Urban to Agriculture Threshold (right) Tradeline to Waterbody Threshold

6. Conclusion and Future Work

The case study of Oran Park examines housing development trends in a climate of rapid urban growth and demand. While the presented model targets the agricultural and flood-prone characters of its context, there is an opportunity to make site-specific adaptations for alternate locations. Through the use of evolutionary methods, a relationship between functional parameters and design goals was constructed, allowing the investigation to address social, environmental and urban challenges within and beyond the site. There is a consistent emphasis on the need for environmental connection to an agrarian, flood-prone site and the expansion of user demographic through variation in building typology and access. The integration of these two distinct systems evolved and strengthened at all stages; starting at the scale of broader site analysis, through the construction of the phenotype and into manual design. The analysis of the two focal thresholds in the selected solution exhibited a newly developed discourse between social and environmental contrasts through an assimilation of accessibility and irrigation networks (both visually and physically). Moving forward with the research, further work is needed to test the developed model on alternative urban sites in Western Sydney, exploring the adaptability of the model to solve similar problems experienced in various suburbs in the region. Moreover, future work will incorporate real-world government policies within the developed model, to transition the presented research towards real-world applications.

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