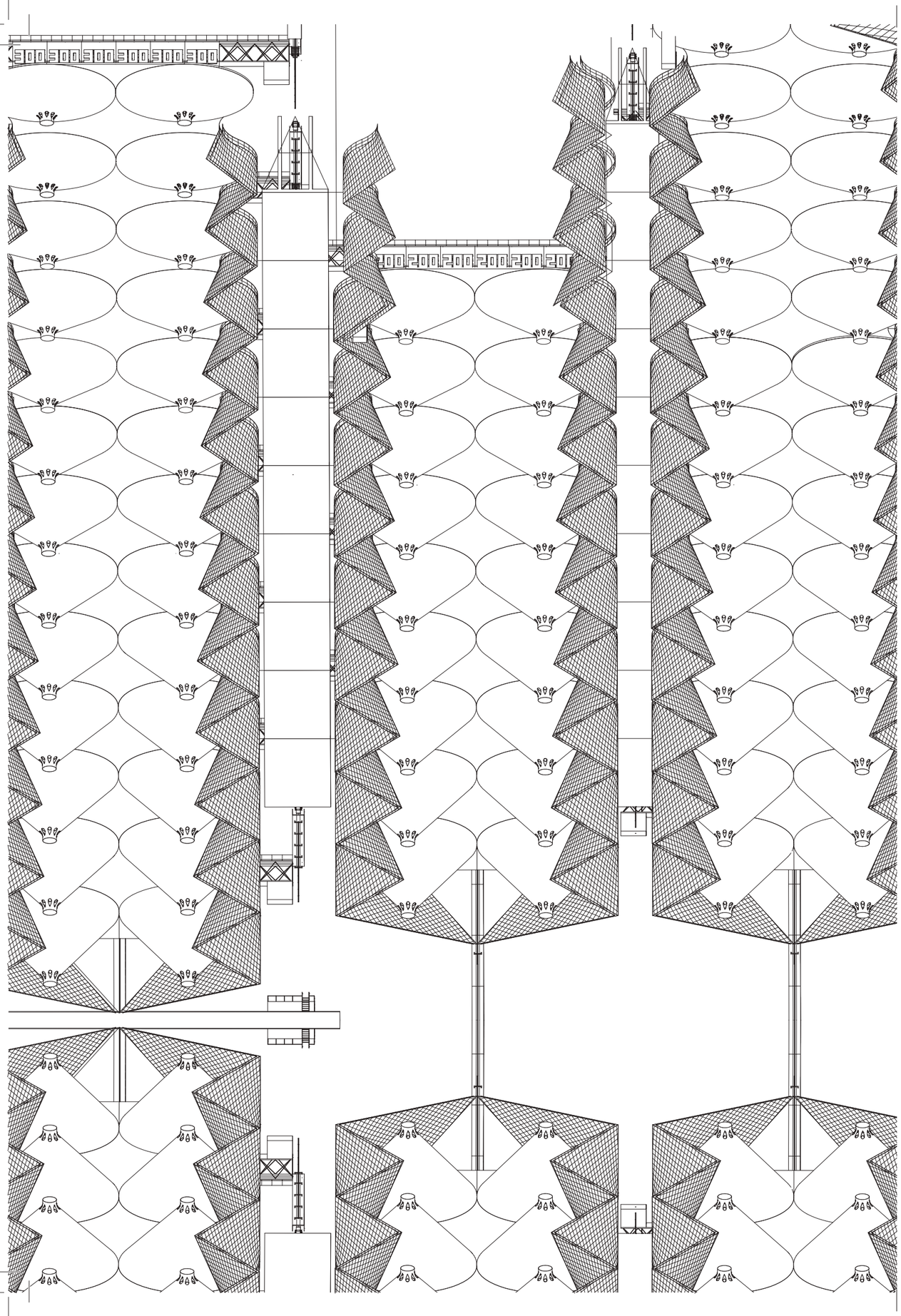
MATERIALISING SAND
28.04.18



MATERIALISING SAND

THE DUNES, THE ARCHIPELAGO, THE BEACH

BY LIN DERONG

THESIS SUPERVISOR DR. LILIAN CHEE

VOLUME 2

ARCHITECTURAL DESIGN THESIS

SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARCHITECTURE

AT THE NATIONAL UNIVERSITY OF SINGAPORE

PRESENTED ON THE 28TH APRIL 2018

Gigantic sand dunes continue to pile as Singapore safeguards her resources amidst global scarcity. Shifting away from sand's instrumentalist narrative, three erratic sandscapes emerge vis-à-vis our three stockpile sites as a hyper-productive leisure infrastructure to recast sand's muted politics and its tactility as an emotive material matter. Performing further as a morphological catalysis, our relationships and vulnerabilities with sand unfold.

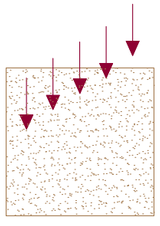
DB000. [Previous Spread] **Tropical Arid.** Standing on Bartley Viaduct. Tampines on second visit, 2018.

DB001. [Opposite] **A small pile of big.** Sand particles in a sand pile. See figure FP103 Sand classification table in *Materialising Sand: Volume 1* for the constitutions of sand as a matter.

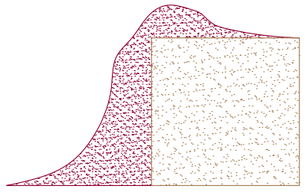
Behaviourology

Our relationship and vulnerabilities with sand are deeply embedded in sand's material properties. Sand is a granular material that consists of particles between 0.06mm to 2mm in diameters as defined in volume 1. They behave in very peculiar ways which are akin to solids, liquids and gases. Each granular particle is capable of accumulating into scales ranging from table piles to sheer territorial landforms. Together, their forms morph with wind, gravity and water.

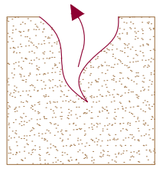
The architecture takes an interest in the materiality of sand – tactile, haptic, scalar – to translate into an alternative experience and ecology. Vis-à-vis Singapore's three sand stockpiles, three surreal sandscapes emerge: the leaky, the flamboyant, and the vast.



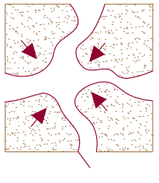
ABSORB



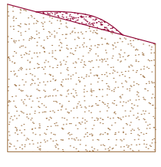
BURY



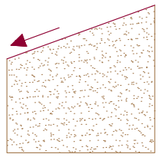
CARVE



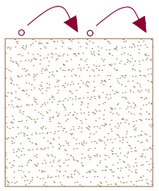
CONGLOMERATE



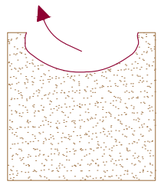
DEPOSIT



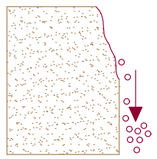
ERODE



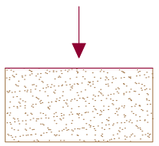
SALTATE



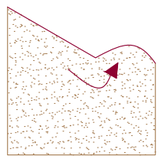
SCOUR



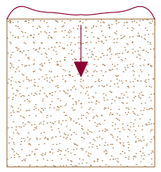
SEEP



SETTLE



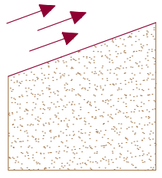
SLUMP*



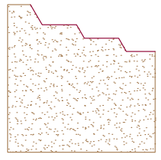
SUBMERGE

DB002. Sand Behaviours Index. Due to sand's material properties, they behave in a certain way upon external forces acting on it. List is not exhaustive. Drawing reconstructed from Allen, 469-471.

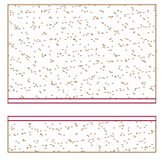
*Slumping occurs when a coherent mass of loosely consolidated sand moves a short distance down a slope. Movement is characterized by sliding along a concave-upward or planar surface



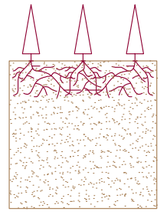
SURGE



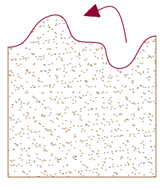
TERRACE



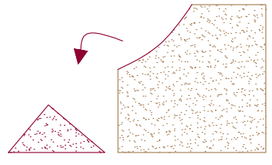
TUNNEL



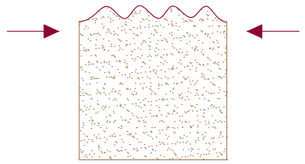
VEGETATE



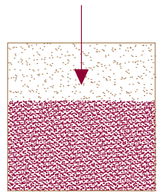
EXCAVATE



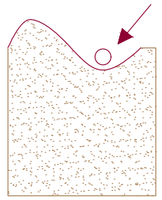
FACET



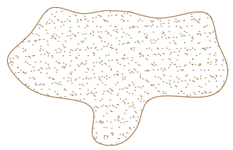
FOLD



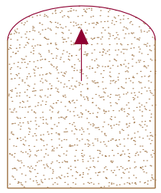
GRADATE



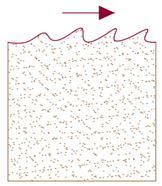
IMPACT



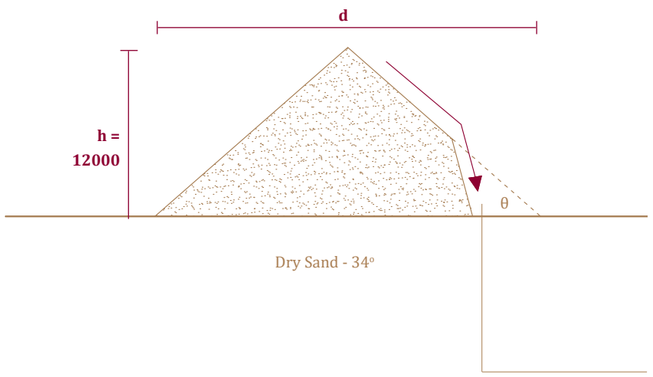
LIQUIFY



REBOUND



RIPPLE



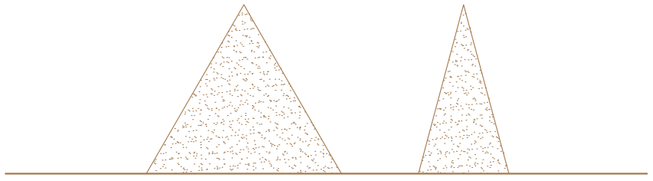
Dry Sand - 34°

Angle of Repose
$= \tan^{-1}(h \div ½\ d)$

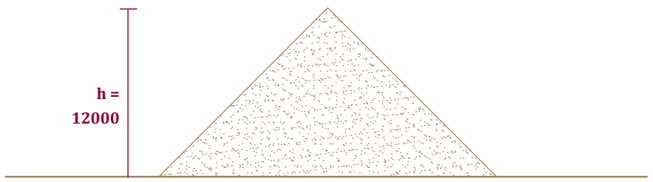
where
$\tan\theta$ = opposite ÷ adjacent
h= height from base to peak
d= base diameter

$\tan 34 = h \div ½\ d$
$34° = \tan^{-1}(2 \times 12000/d)$
$d = 24000 \div \tan(34)$
d = 35600mm (3 s.f.)

Sand will fall on slip-face by breaking the particle tension, and fill up the gap. This process will repeat overtime under gravity and material weakness.



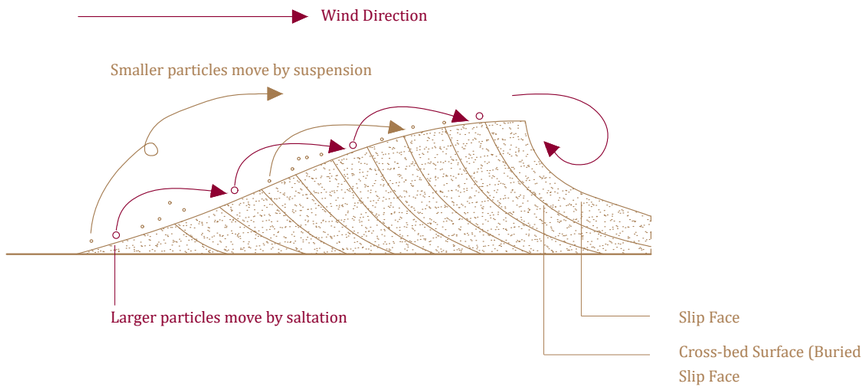
Sand (water filled)
30° to 15°

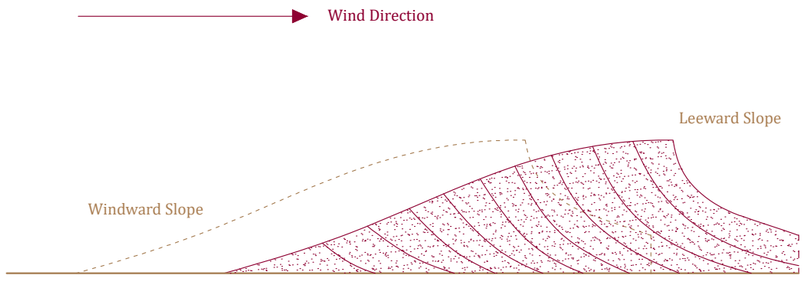


Wet Sand - 45°

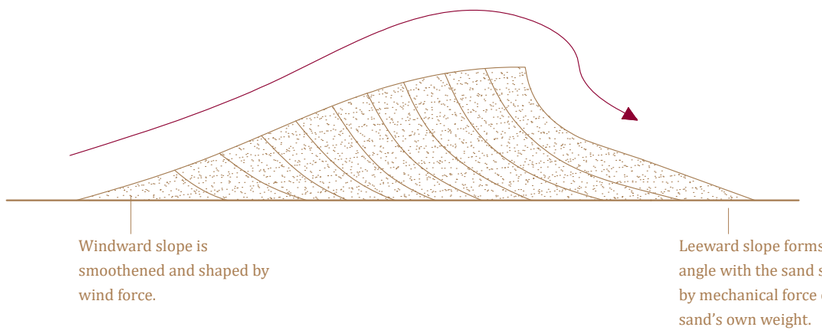
$45° = \tan\text{-}1[(2 \times 12000) \div d)$
$d = 24000 \div \tan(45)$
d = 24000mm

DB003. Angle of Repose. This is the steepest angle of dip relative to the horizontal plane to which sand can be piled without slumping, anything more, slope surface will slide. Sand has a predetermined angle of repose from 34° to 45°. Generally, the rougher the grains the steeper the angle due to their ability to better interlock. Reference: Glover, Thomas J. P*ocket Ref.* 4th ed. Sequoia Publishing, 2010.

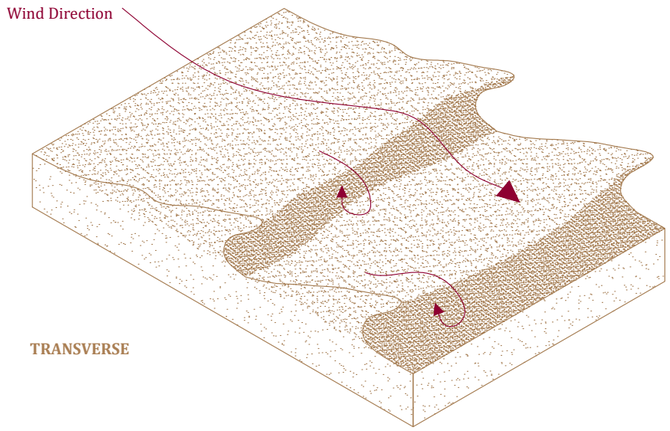




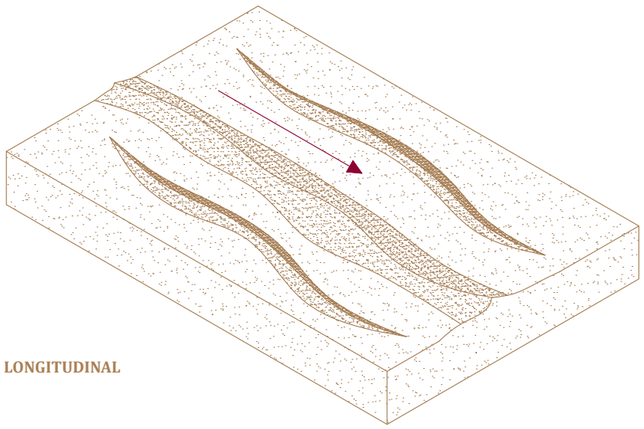
Dune Migration



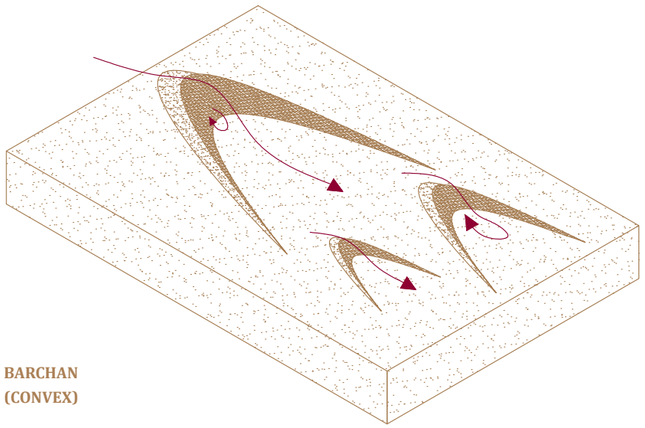
DB004. Sand Dune Profile.



TRANSVERSE

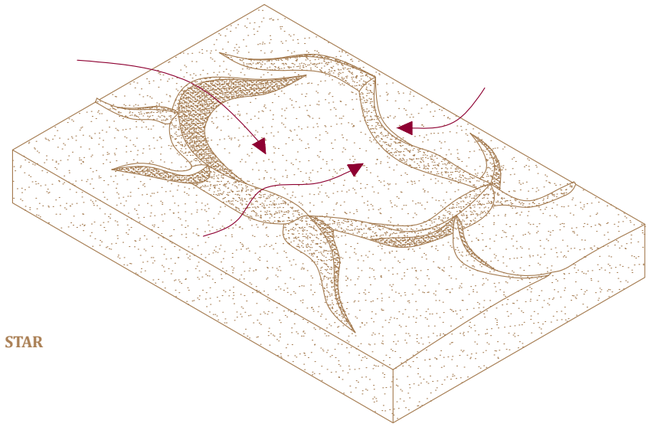


LONGITUDINAL

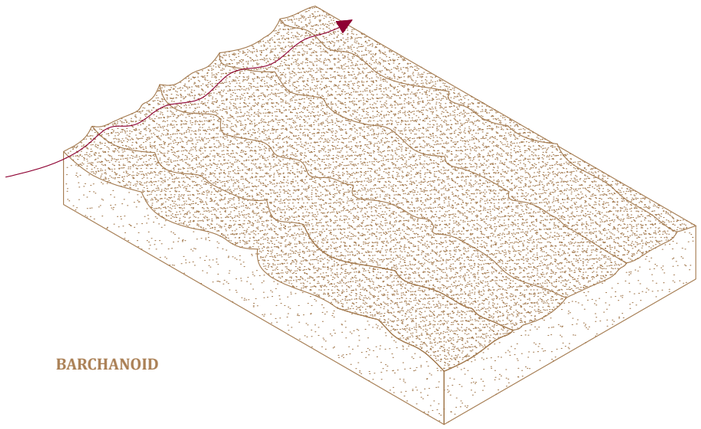


BARCHAN
(CONVEX)

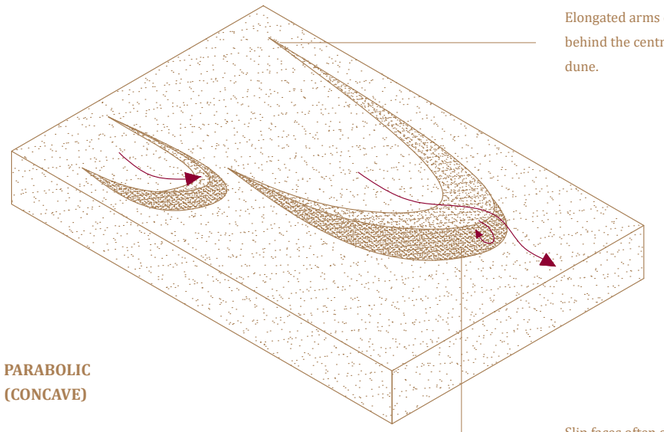
DB005. Aeolian Sand Dunes. Geometries shaped naturally by wind velocity and sand supply. Sand particles moves with the wind direction. These typologies are found in different places on the Earth's surfaces according to global wind movements.



STAR



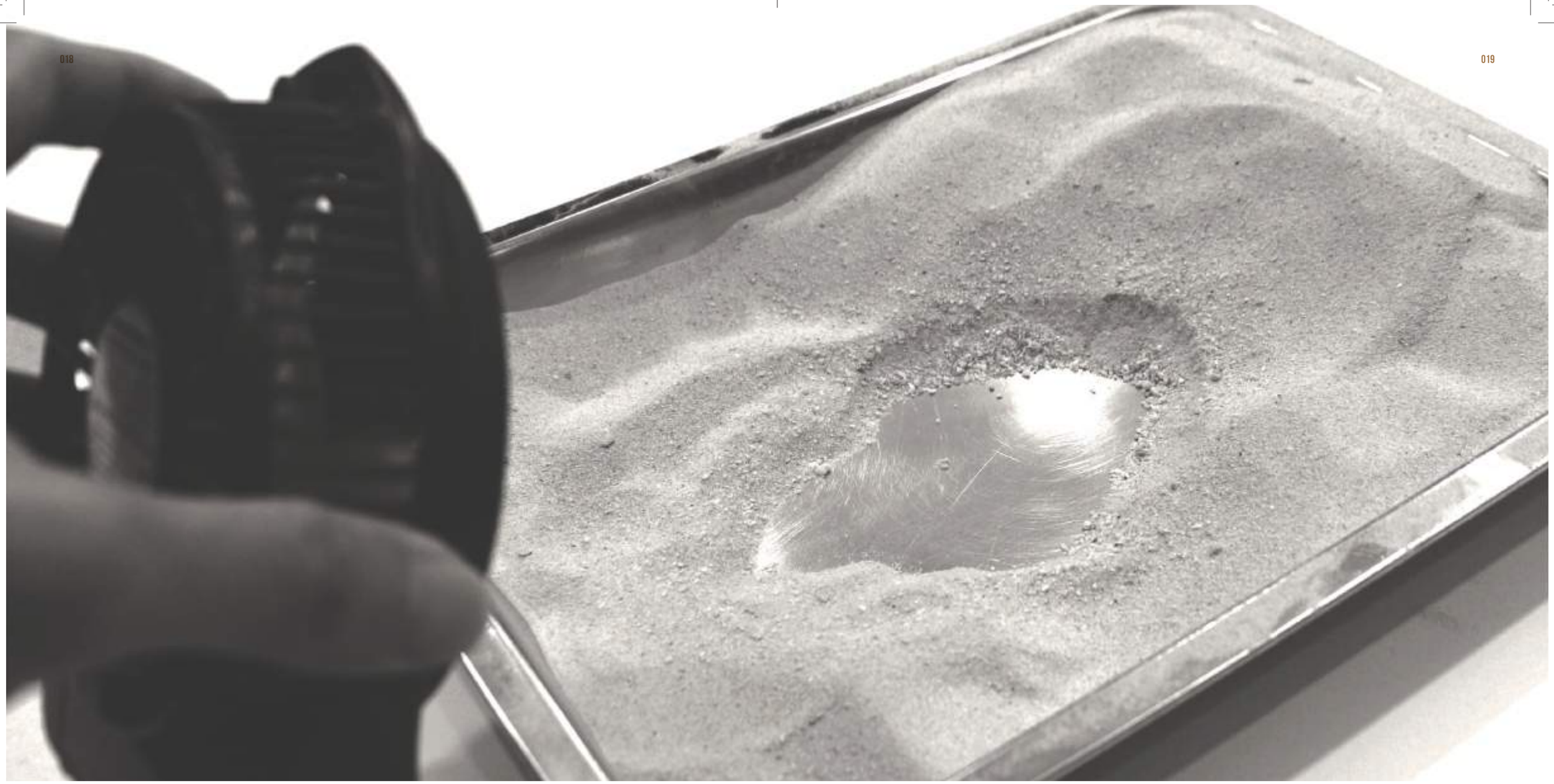
BARCHANOID

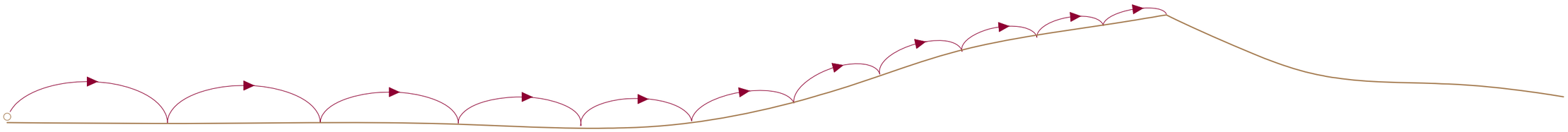


Elongated arms extend upwind behind the central part of the dune.

Slip faces often occur on the outer side of the nose and on the outer slopes of the arms.

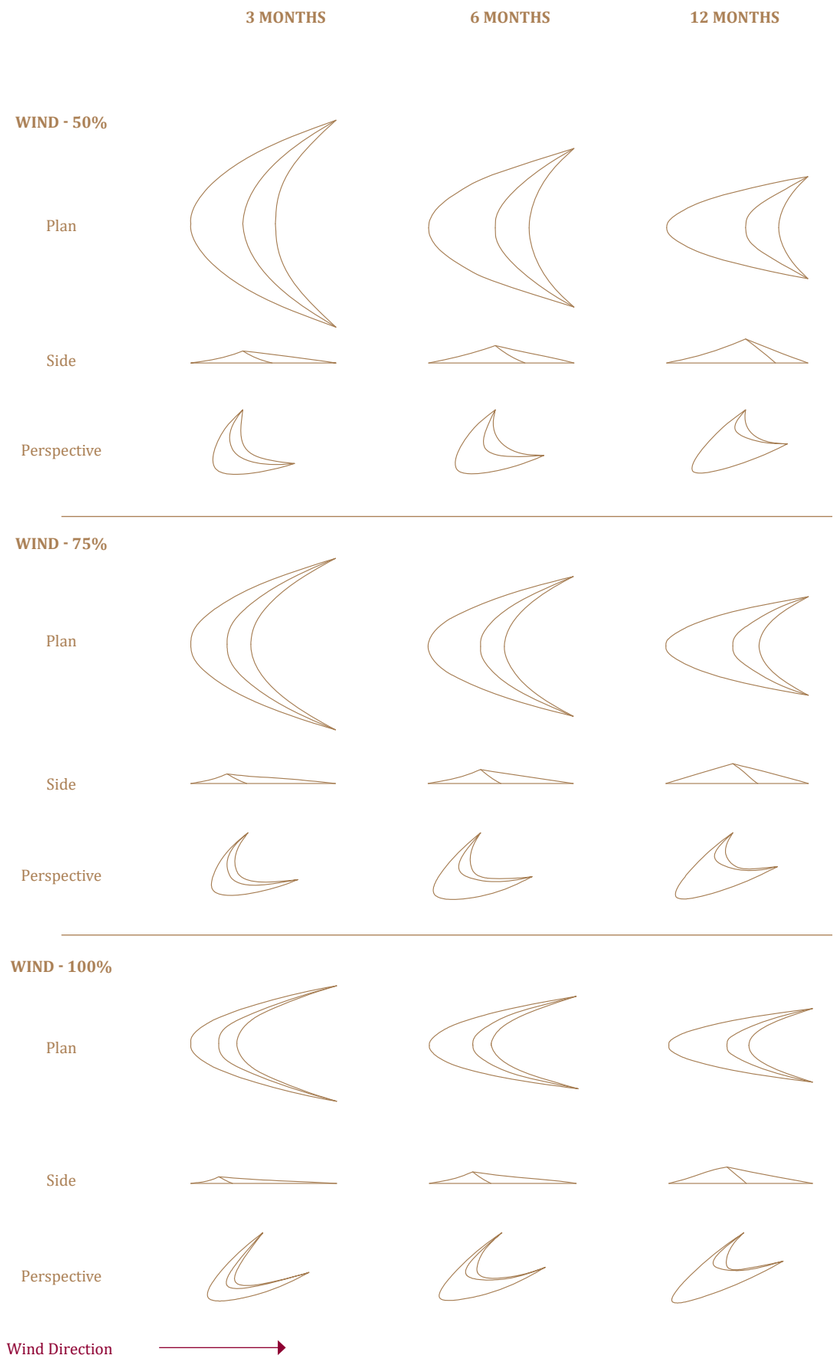
PARABOLIC
(CONCAVE)



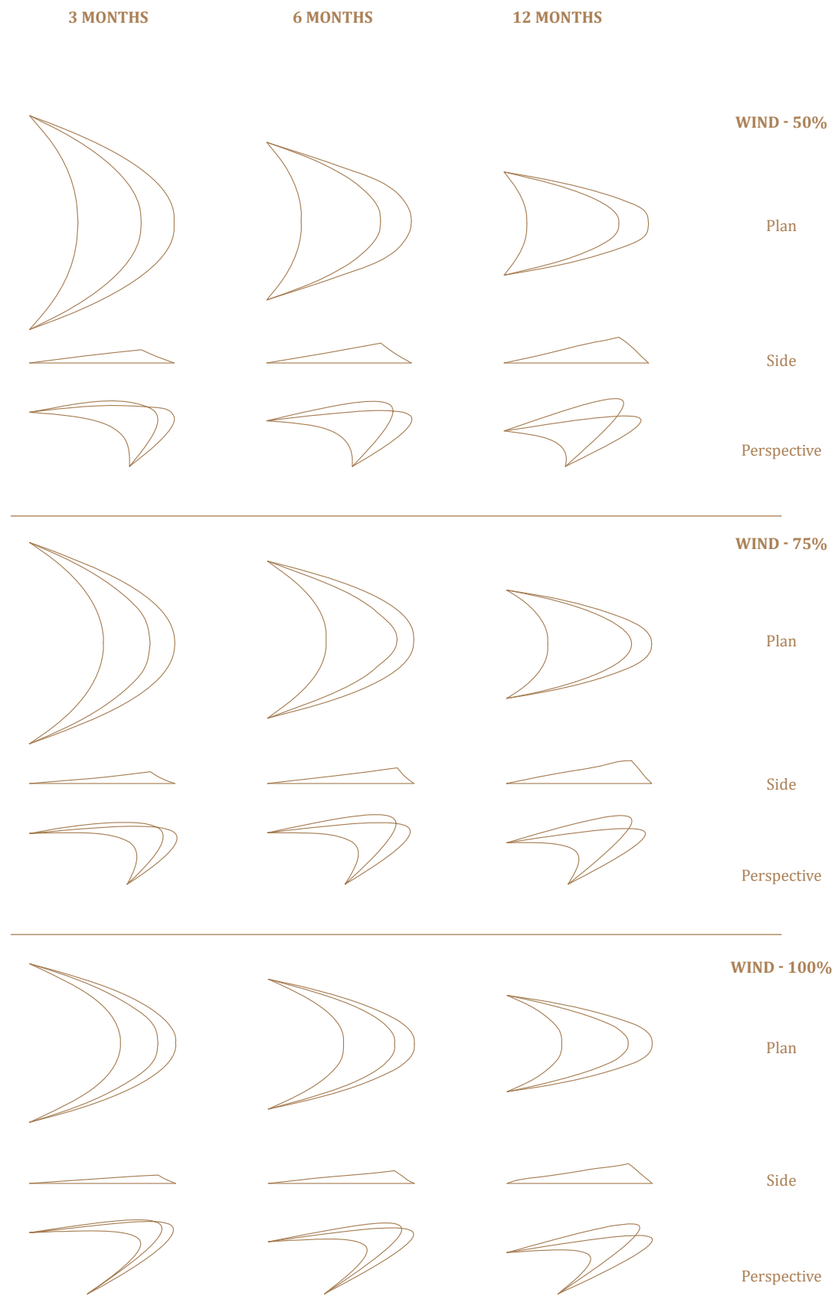


DB006. [Above] **Wind Simulations.** Performed under artificial condition, sand as an aggregate pile morphs, shifts position, and oeirntates with wind movement as each grain saltates, suspends and displaces.

DB007. [Below] **Particle Saltation.** Performed under artificial condition. Sand as an aggregate pile morphs and shifts position with wind movement as each grain saltates, suspends and displaces.



DB008. Barchan Typology. Postulated (convex) sand dune alteration with varying wind speed over a period of 12 months. Referenced from Kotenko, Anastasia, and Niki Kakali. 'Aeolian Sand Odyssey'. Landscape Urbanism, Architectural Association, 2014.

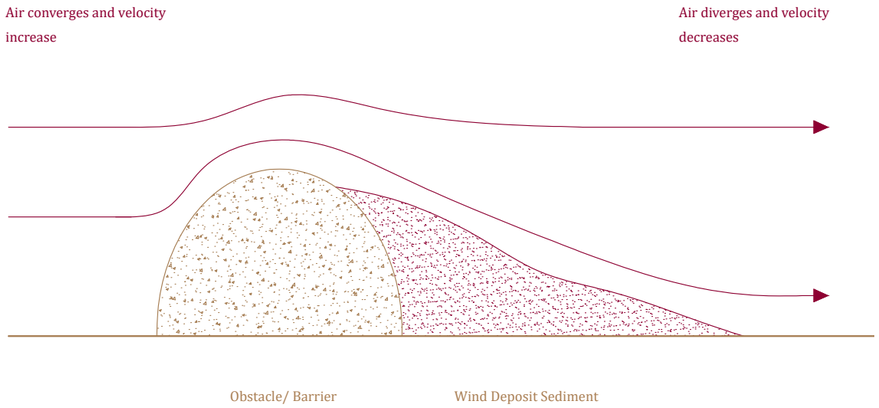


DB009. Parabolic Typology. Postulated (concave) sand dune alteration with varying wind speed over a period of 12 months. Referenced from Kotenko, Anastasia, and Niki Kakali. 'Aeolian Sand Odyssey'. Landscape Urbanism, Architectural Association, 2014.

Aeolian Sand and Obstacles - Sediments
Air converges and wind velocity increases as they pass through a physical barrier/ obstacle. Airborne sand particles travelling by suspension will deposit as sediment on the leeward side as air diverges and wind velocity decrease. Overtime, sand will accumulate.

DB010a. Plan of Deposit.

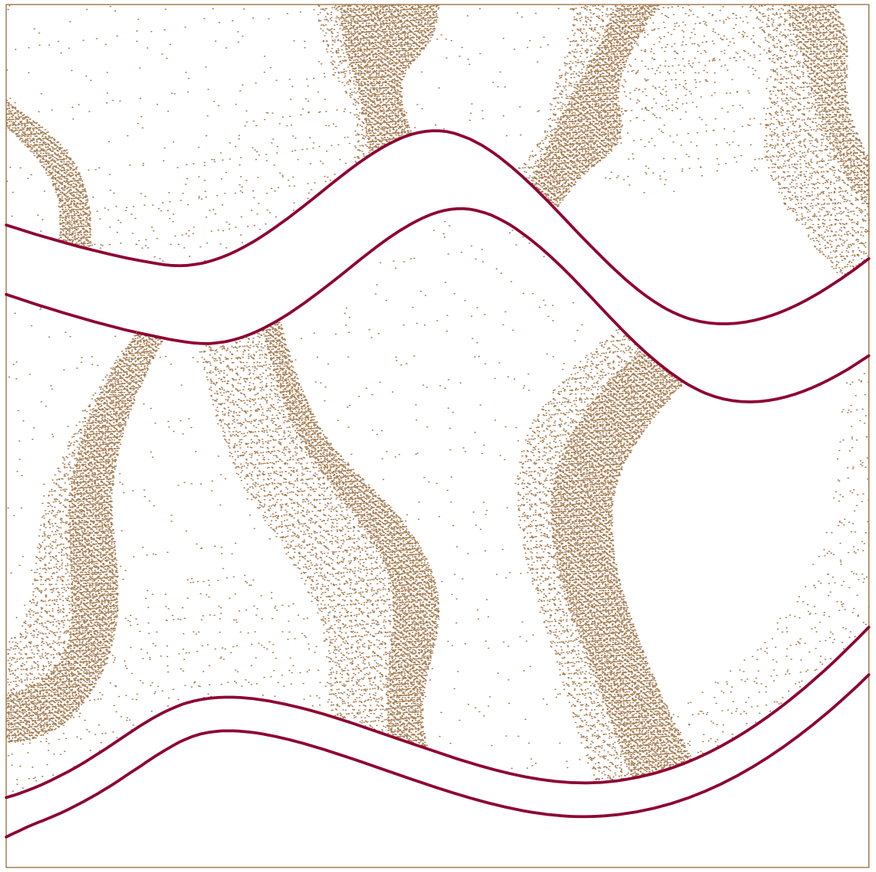
DB010b. [Opposite] **Section Profile of Deposit.**



DB011a. Obstacles and Artificial Conditions. An abstract object is placed in the middle of a sand pile where conditions are artificially exaggerated and controlled to expedite the morphology process and achieve certain forms on purpose.

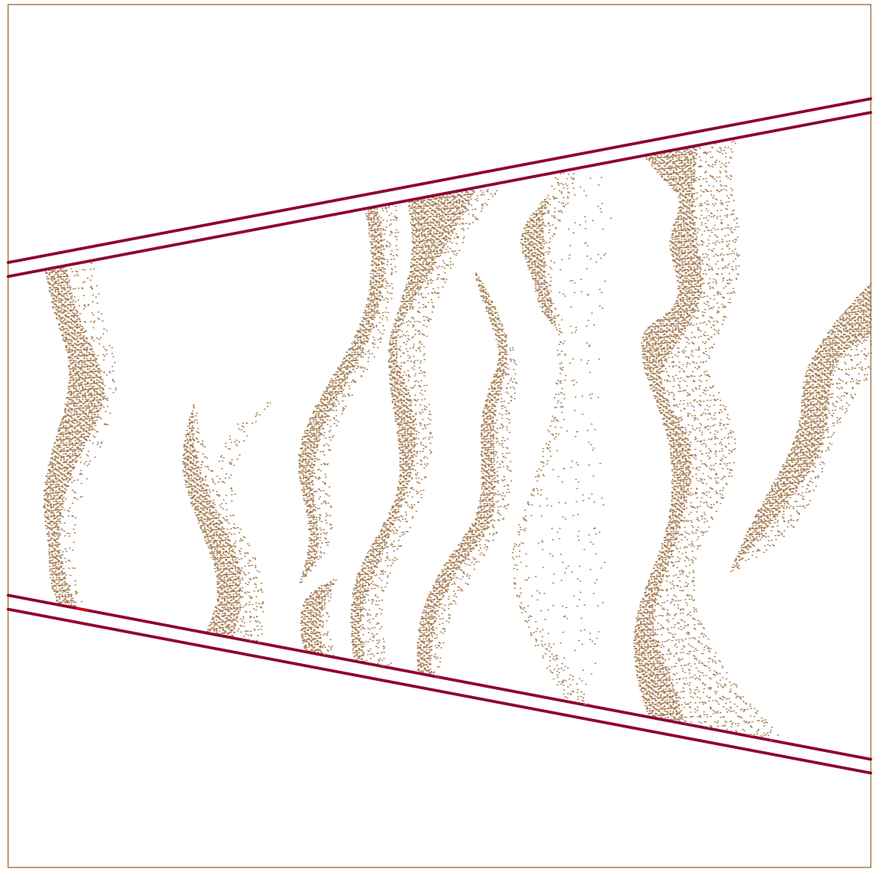
DB011b. Expedited Burial. As sediments accumulate overtime, the obstacle will eventually be buried in sand.

Aeolian Sand and Obstacles - Morphology Simulation
Abstract physical obstacles are introduced to alter dune's movement direction, and also creating paths for dunes to morph. The experiment attempts to learn simple organisation techniques to achieve specific morphologies. Naturally, these processes will take several decades.
Referenced from Kotenko, Anastasia, and Niki Kakali. 'Aeolian Sand Odyssey'. Landscape Urbanism, Architectural Association, 2014.

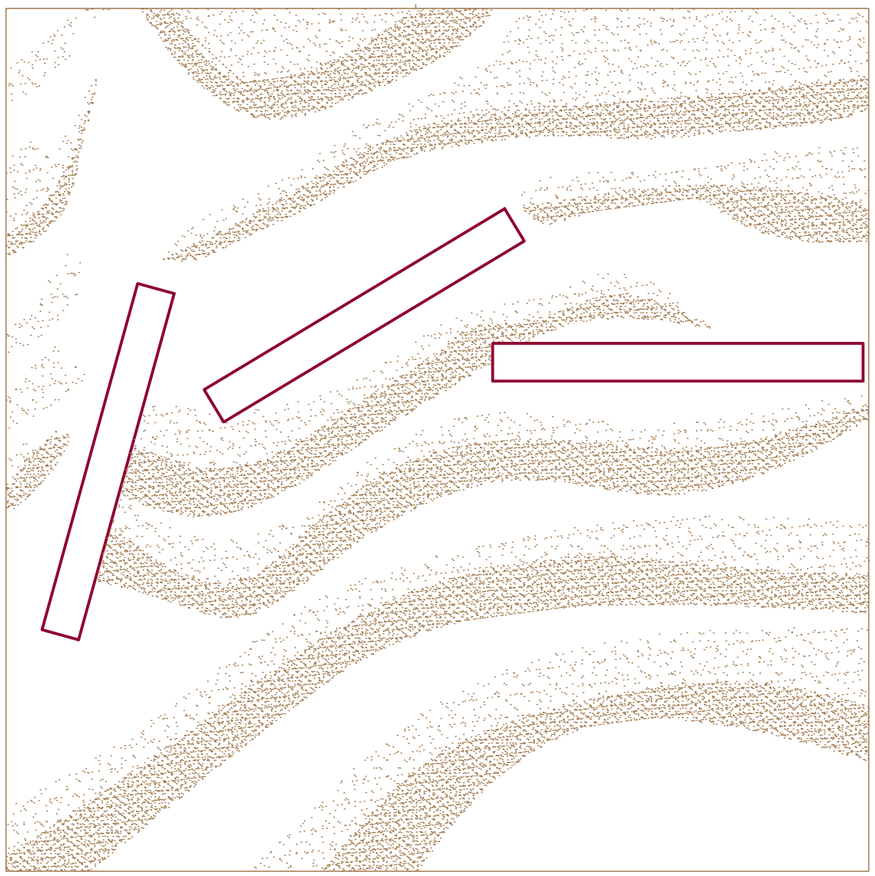


DB012a. [Opposite] **Obstacle Simulation A.** Obstacles with an angle to the wind flow shape the dune movements perpendicular to themselves - turning dunes movement direction.

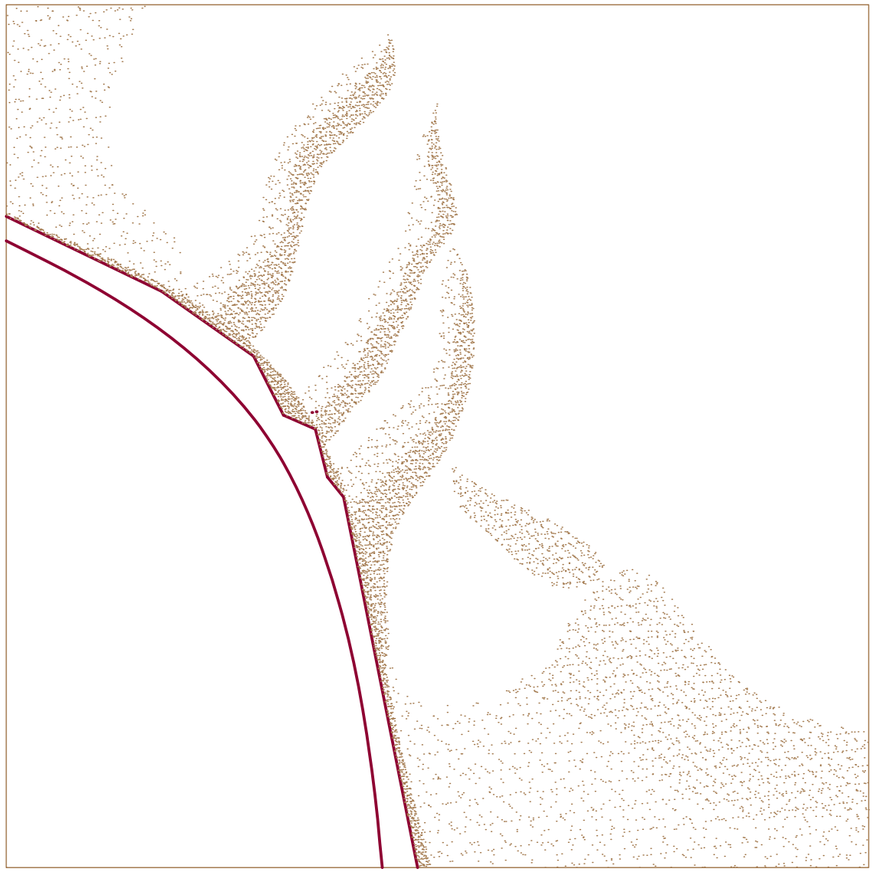
DB012b. Obstacle Simulation B. Straight wall variation.

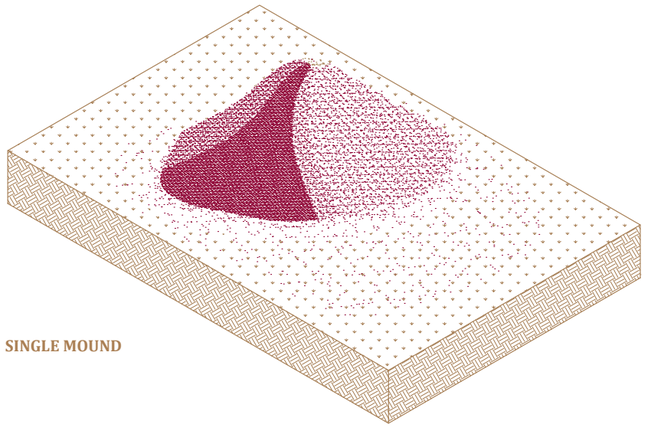


DB012c. Obstacle Simulation C. Dunes tend to turn their crest parallel to the obstacles they meet with in their moving direction/ wind direction.

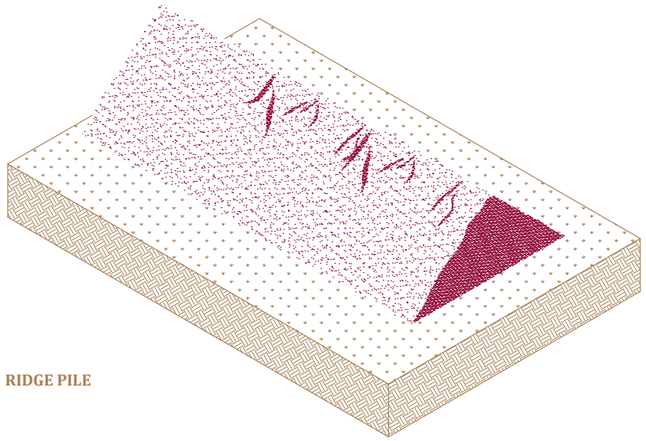


DB012d. Obstacle Simulation D. Obstacles with an angle to the wind flow shape the dune movements perpendicular to themselves - turning dunes movement direction.

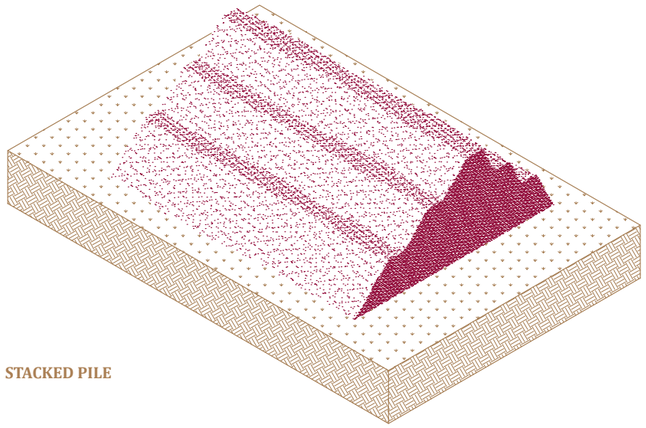




SINGLE MOUND

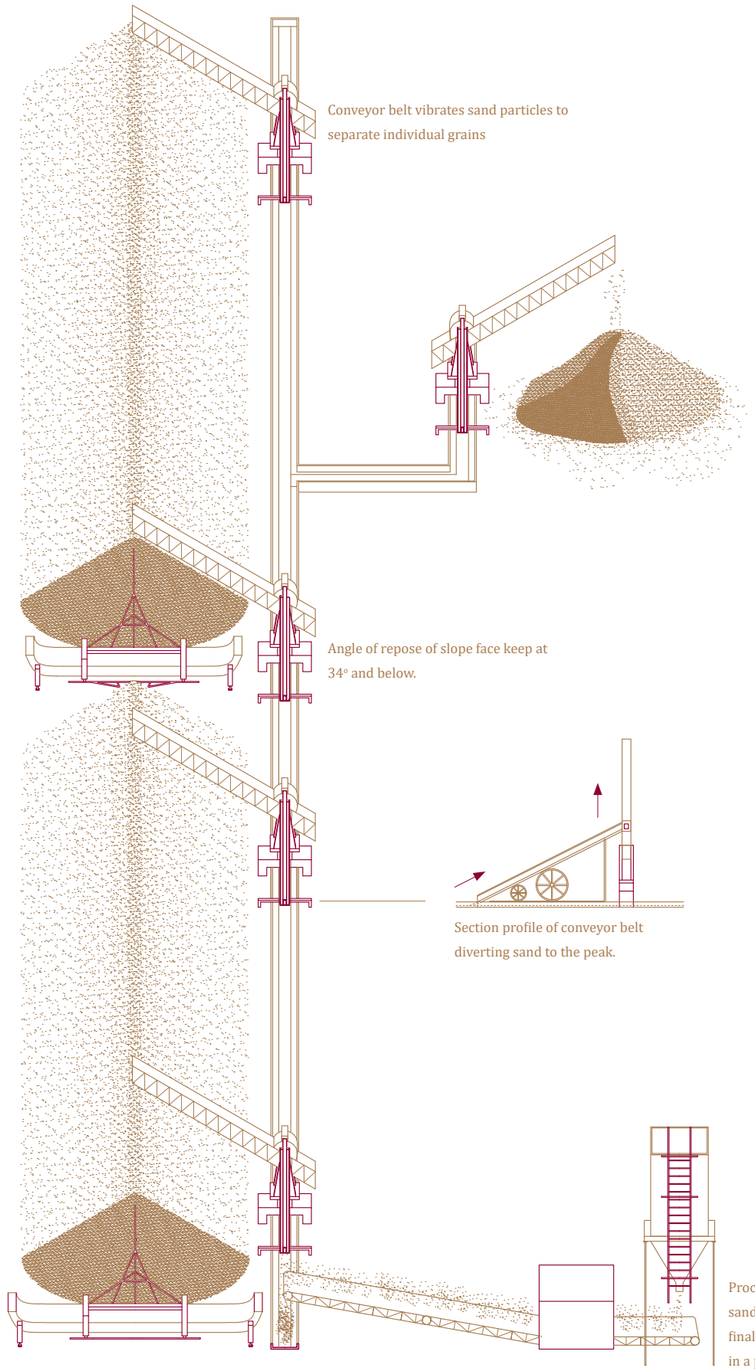


RIDGE PILE



STACKED PILE

DB013. Artificial Sand Pile. Geometries formed as a result from pragmatic storage purpose - fresh off conveyor mills and sand barges. These typologies are found in sand stockpiles.

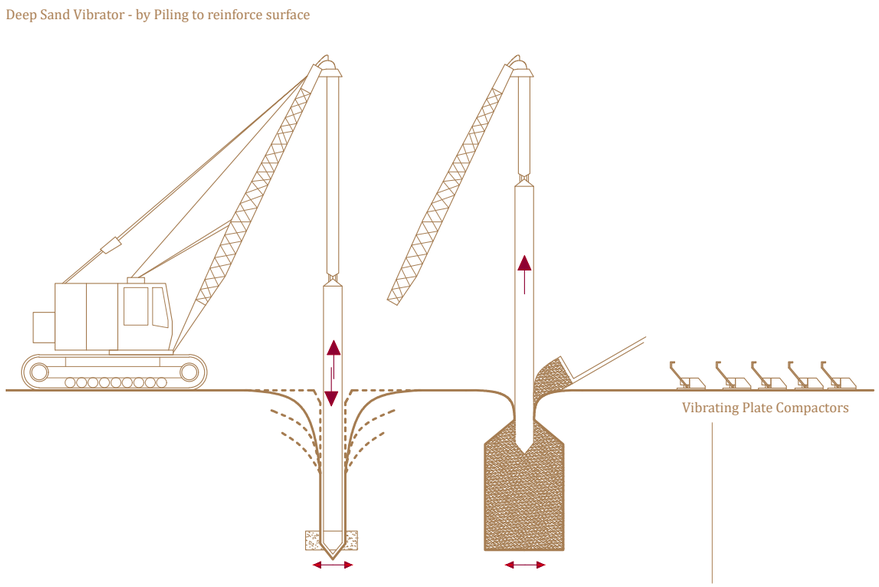


DB014. Piling Sand. Drawing based on observations outside a cement plant in Punggol. Extension to figure AA06 Formation Method: Artificial Sources, and AA07 Frac Sand Plant Process of *Materialising Sand, Volume 1.*

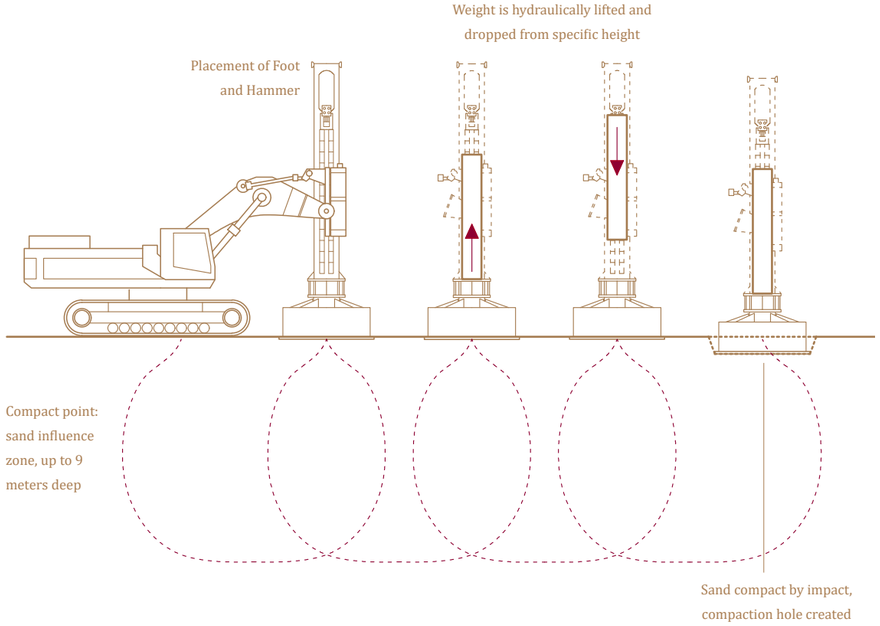
Scale [1:150]

DB015. [Opposite] **Sand Terrace.** Tampines on second visit.

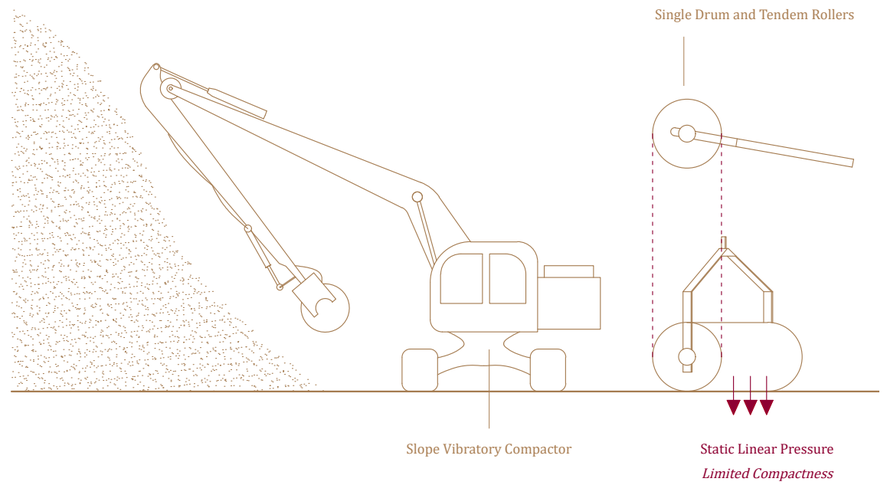
DB016. White Mounds. Tampines on second visit.



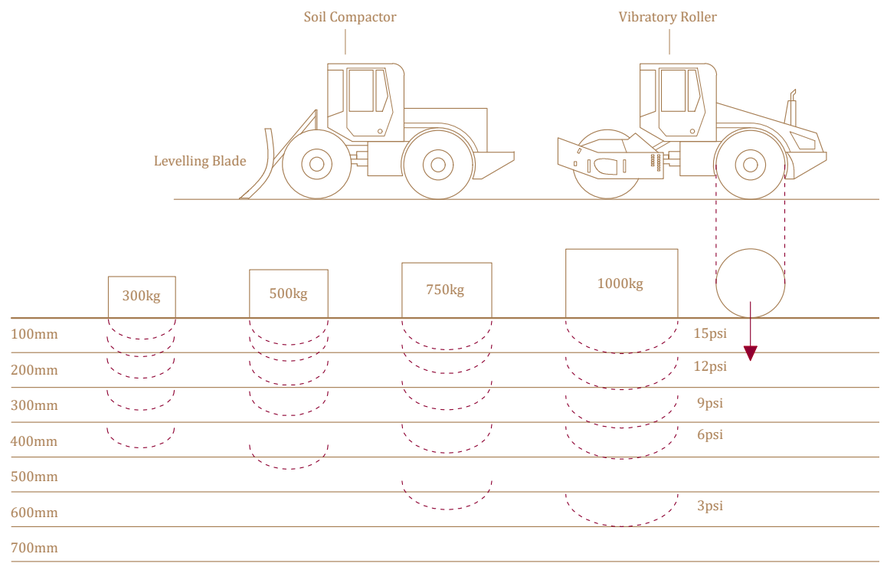
DB017a. Compacting Sand - Vibration. Heavy duty Stress is applied repeatedly and rapidly via a mechanically driven hammer. Often combined with rolling compaction. Drawing not to scale.



DB017b. Compacting Sand - Impact. Stress is applied by dropping a large mass onto the surface of the soil. Drawing not to scale.



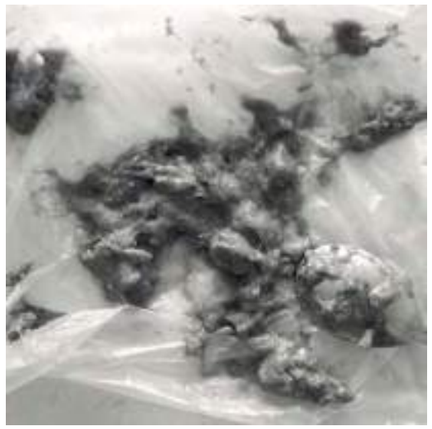
DB017c. Compacting Sand - Static. A large static stress and pressure is added on the surface and then released overtime. Drawing not to scale. Reference from Mishra, Gopal. 'Different Types of Soil Compaction Equipments -Types of Rollers'. Accessed 31 March 2018.



DB017d. Compacting Sand - Rolling. A heavy cylinder is rolled over the surface of the soil. Often fitted with vibratory devices. Commonly used on sports pitches. Reconstructed from Danneberger, Karl. 'The Science of Soil Compaction'. *SportsField Management*, 2013. Drawing not to scale.

Sand Pile Casting. Small amount of water is able to bind the gaps between particles. Electrostatic attraction of water to mineral surfaces will increase soil strength.

DB018a. Mixture A. 1 : 1 [Sand : Water]
DB018b. Mixture B. Kinetic Sand with Scenic Spray
DB018c. Mixture C. 1 : 1/8 [Sand : Water]
DB018d. Mixture D. 1: 1/8 [Sand : Seawater]
DB018e. Mixture E. 1 : ½ : ¾ [Sand : Cornstarch : Water]
DB018f. Mixture F. 2 : 1 : 1 [Sand : White Glue : Cornstarch]
DB018f. Cooking mixture E over heat.



There is a principle specific to environmental ecology: it states that anything is possible – the worst disasters or the most flexible evolutions

- Felix Guatarri, "The Three Ecologies", 1989

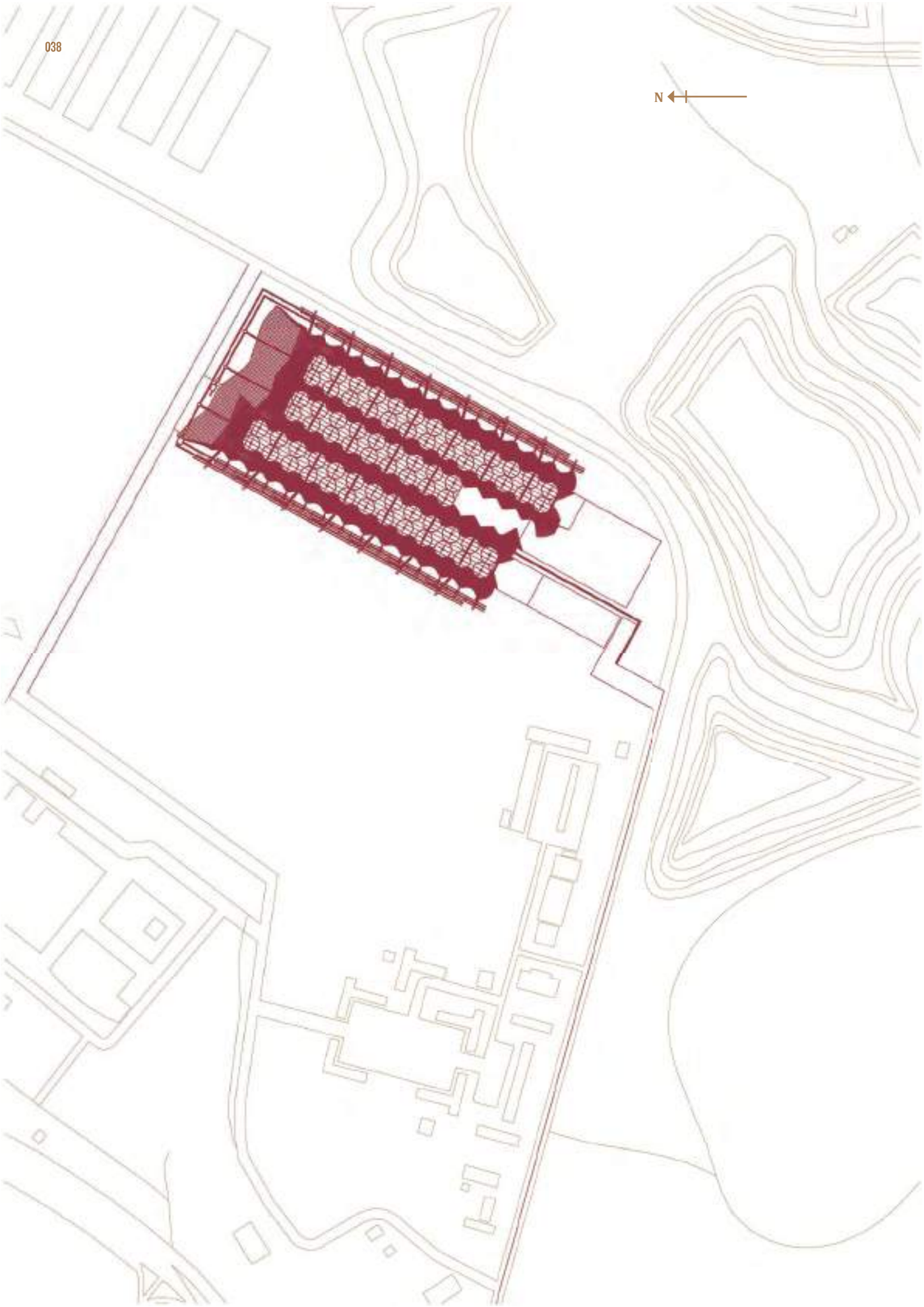
The architecture interventions are set to blur the boundaries between architecture and landscape. In Antoine Picon's words, it is a convergence of "abstract information and tangible sensation". Whereas architecture is understood as an abstraction, landscape is traditionally associated with tangible materiality and sensation. In the reconciliation between conceptual and tangible, constructing these interventions involve negotiating through challenging realms as the site contexts impose their technical limits – practicality, access, codes, programmatic performances – set within a defined architectural context.

Using landforms created by sand and its material properties, three sandscapes – a series of dunes, an archipelago, and a beach – emerge and transform into extreme forms of landscape. Beyond pastoral images, they make use of the three site contexts and their corresponding associative uses of sand – a shooting range, a barge cruise, and an infinity sand-pool. These are artificially constructed grounds made to activate sand's tactility, materiality, performance, texture and properties. Sand becomes unpredictable and at times, risky. They leak, erode, slump, bury, shift, morph, deplete and accumulate, and they are ever changing; challenging the static and inert state of sand in the stockpiles. As compared to their counterparts in the natural realm, these morphological processes are architecturally tampered with and hastened; while leaving these supposedly arid and dry landforms readily at the disposal of Singapore's hot and wet climate.

Combined with the primacy of sand's materiality, the landscape is immersive, haptic, and experienced directly by the body. Users would have to climb, scale, and traverse across these vast landscapes while playing and tampering with the terrains. Being excessive and exaggerated, these hyper-productive leisure infrastructures *become* zones of differences to bring forth an alternative experience with sand whereby an aesthetic dream is built-up.

Through their tangible material consequence and immaterial experience of sand operating on both an intimate and colossal scale, the affective is hence generated while exposing the symbiotic relationships between people and sand.

Three Sandscapes



DS001. Seletar Intervention. Scale [1:5000 on an A4]

DS002. [Overleaf] **Dunes Pattern.** Scale [1:500 on an A4]

[Stockpile] Storage of sand, imported and/or extracted material matter.

[Dunes] Any accumulation of sand-size, windblown materials. Supports a wide range of flora and fauna.

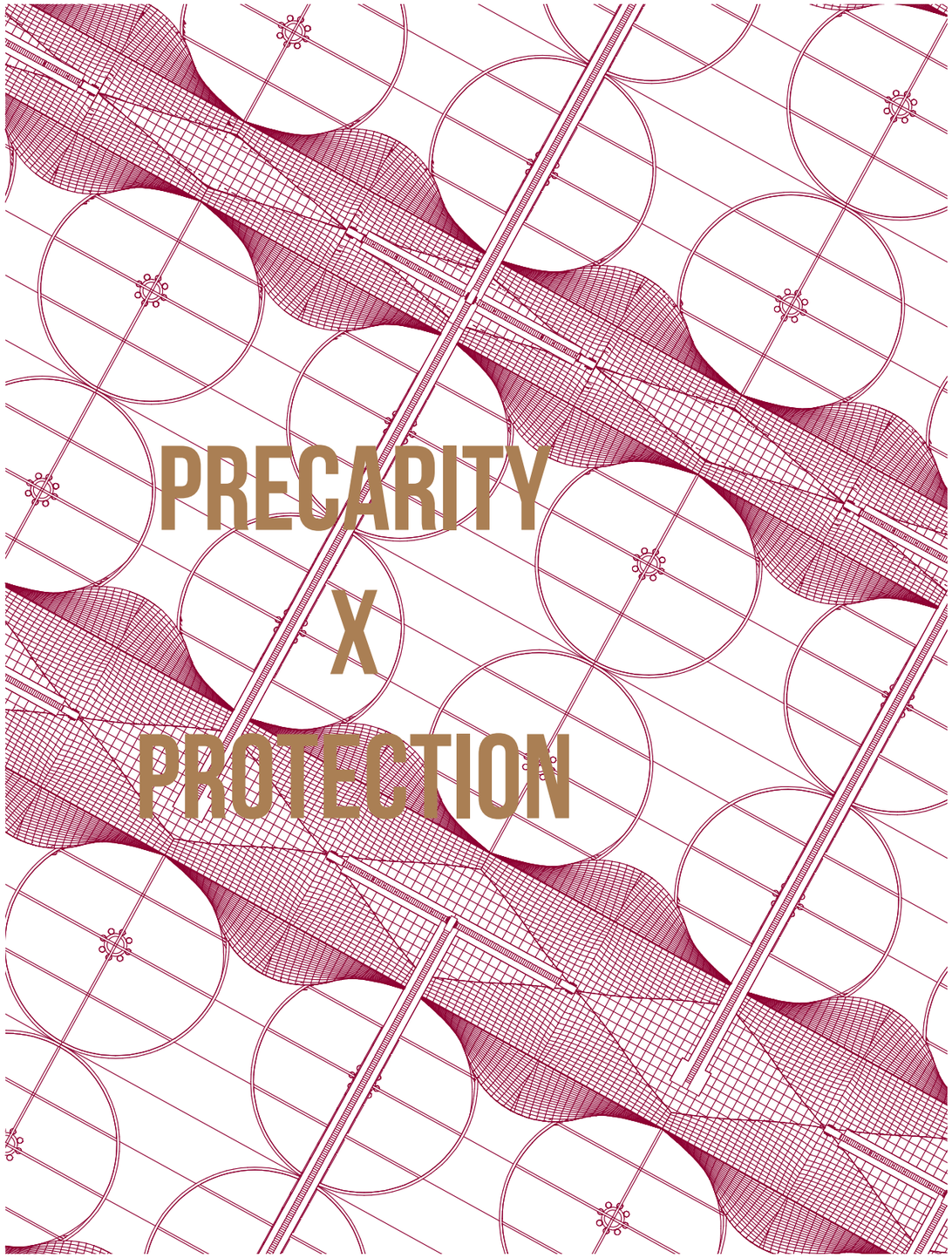
[*Super Dunes*] A Shooting Range. Supports shooting and bomb disposal activities as a soft barrier and trap for shrapnel.

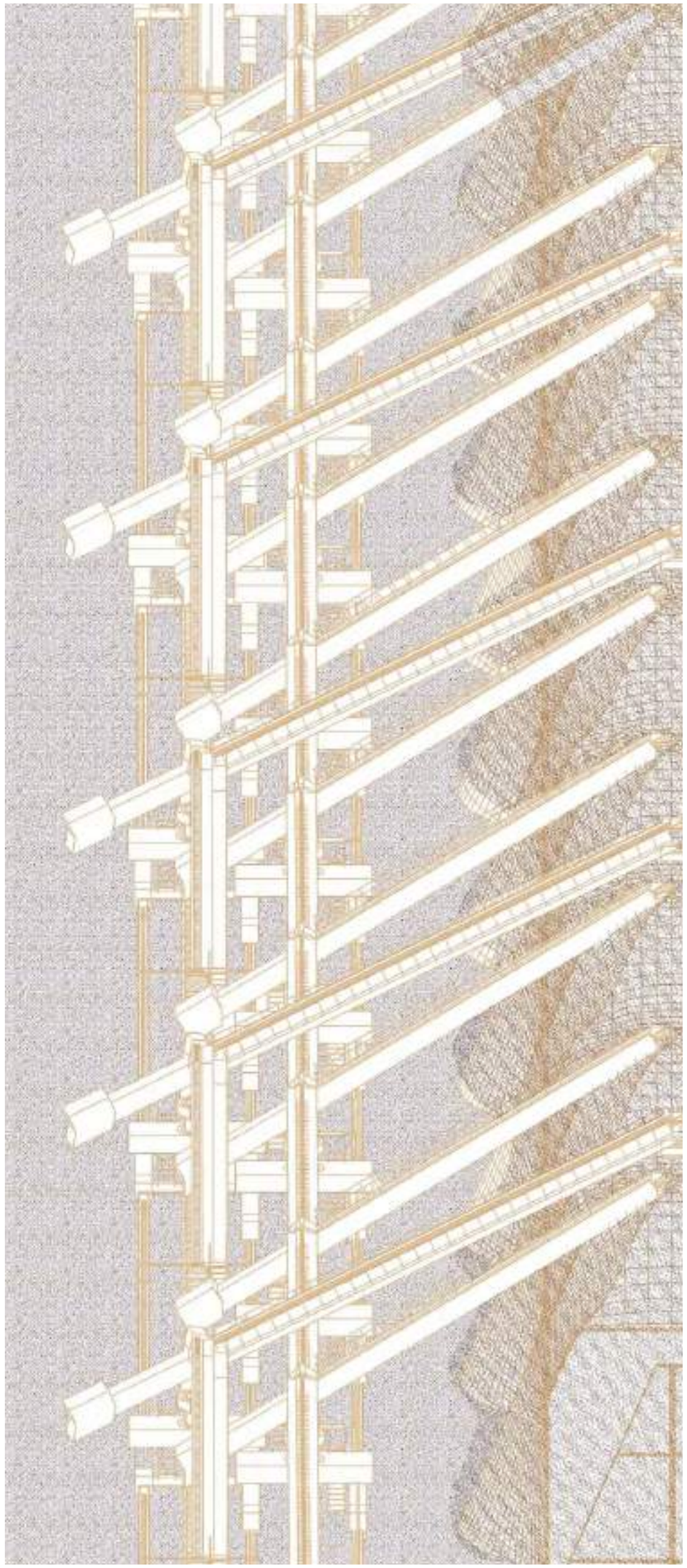
99,000m²

Military Training Ground
Explosive Ordinance Disposal
Public Shooting Sport
Paintball Arena
Sand Maintenance

THE DUNES

Seletar | Shooting Range

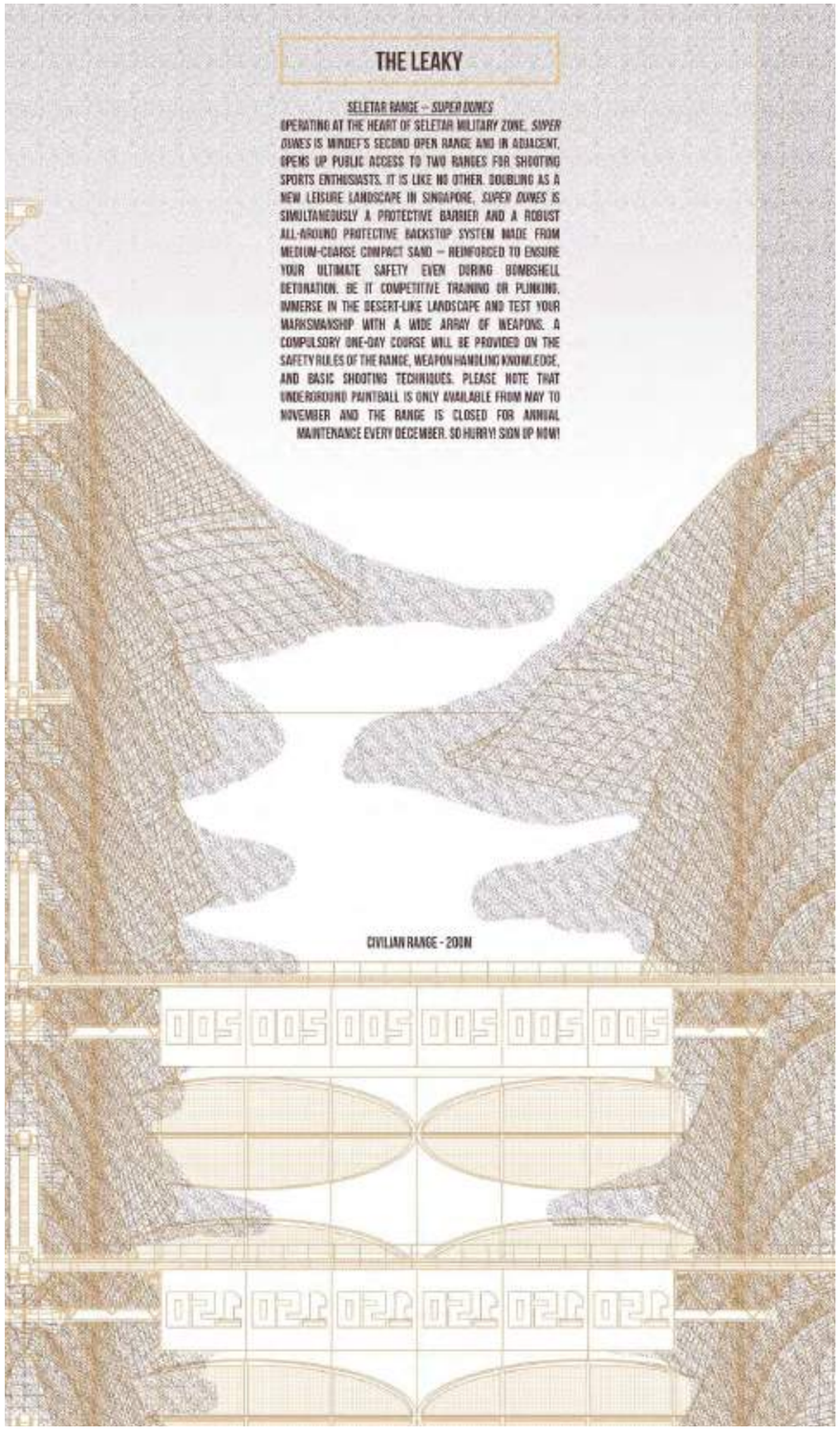


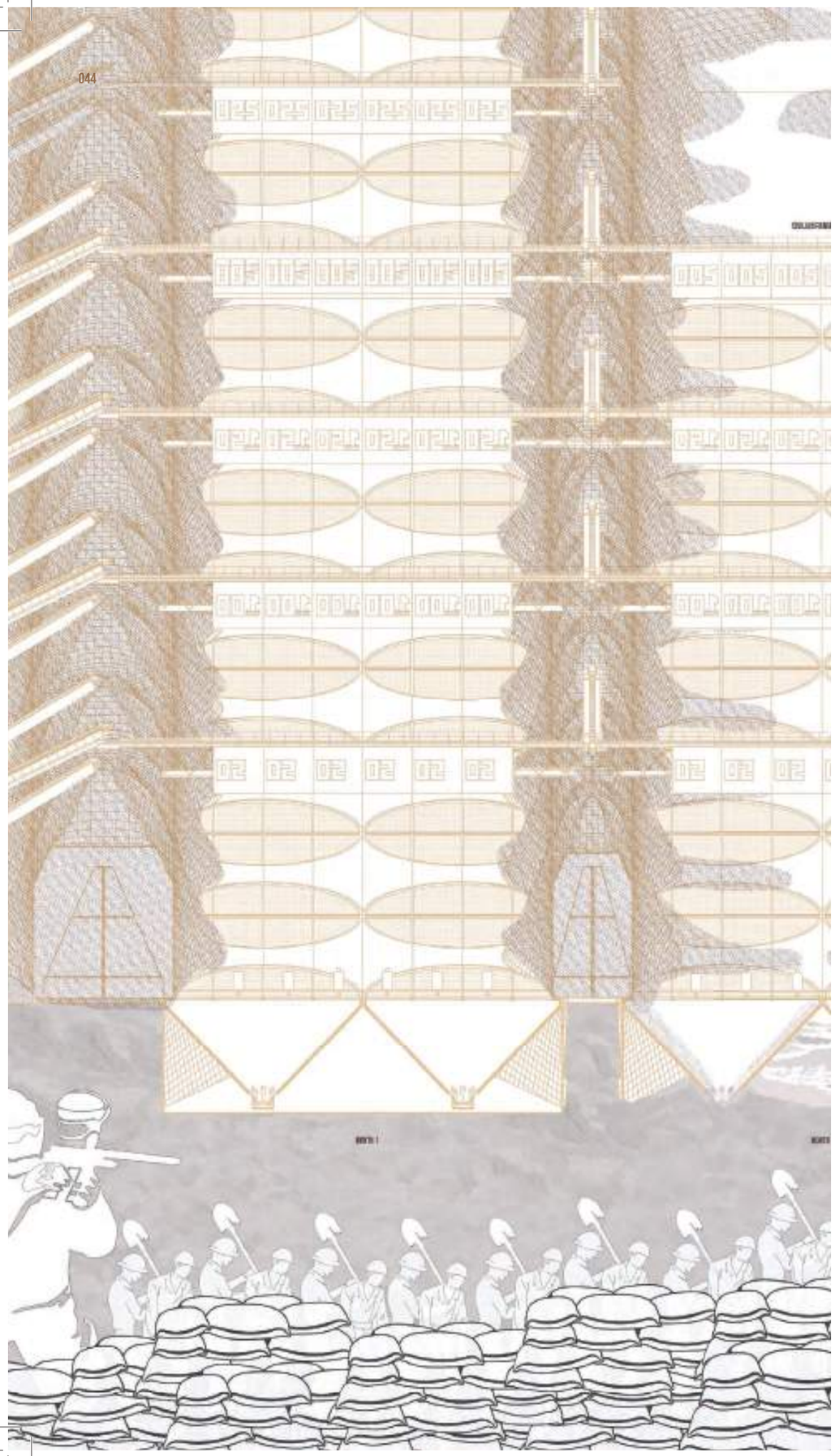


THE LEAKY

SELETAR RANGE – *SUPER DUNES*

OPERATING AT THE HEART OF SELETAR MILITARY ZONE, *SUPER DUNES* IS MINDEF'S SECOND OPEN RANGE AND IN ADJACENT, OPENS UP PUBLIC ACCESS TO TWO RANGES FOR SHOOTING SPORTS ENTHUSIASTS. IT IS LIKE NO OTHER. DOUBLING AS A NEW LEISURE LANDSCAPE IN SINGAPORE, *SUPER DUNES* IS SIMULTANEOUSLY A PROTECTIVE BARRIER AND A ROBUST ALL-AROUND PROTECTIVE BACKSTOP SYSTEM MADE FROM MEDIUM-COARSE COMPACT SAND – REINFORCED TO ENSURE YOUR ULTIMATE SAFETY EVEN DURING BOMBSHELL DETONATION. BE IT COMPETITIVE TRAINING OR PLINKING, IMMERSE IN THE DESERT-LIKE LANDSCAPE AND TEST YOUR MARKSMANSHIP WITH A WIDE ARRAY OF WEAPONS. A COMPULSORY ONE-DAY COURSE WILL BE PROVIDED ON THE SAFETY RULES OF THE RANGE, WEAPON HANDLING KNOWLEDGE, AND BASIC SHOOTING TECHNIQUES. PLEASE NOTE THAT UNDERGROUND PAINTBALL IS ONLY AVAILABLE FROM MAY TO NOVEMBER AND THE RANGE IS CLOSED FOR ANNUAL MAINTENANCE EVERY DECEMBER. SO HURRY! SIGN UP NOW!

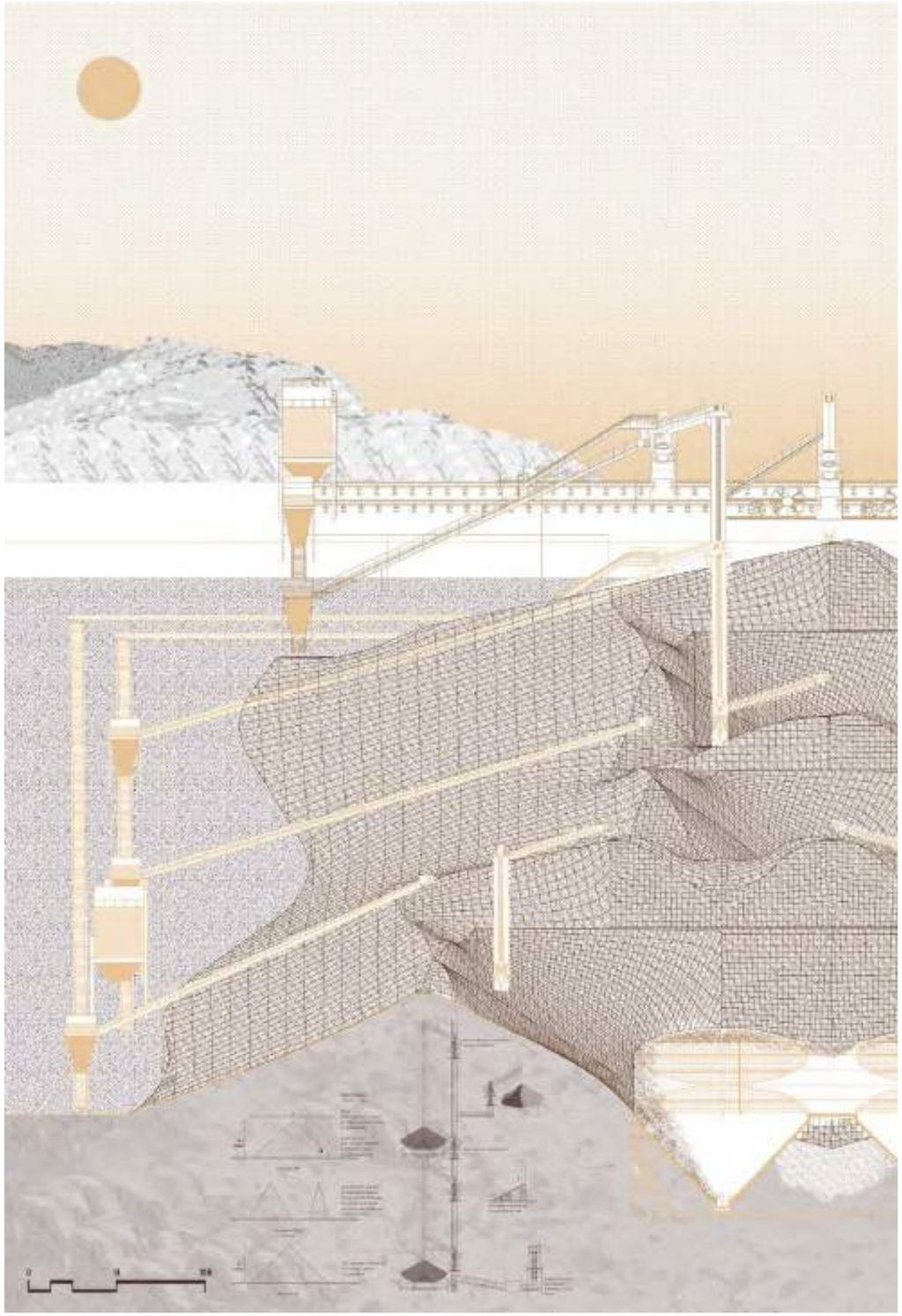


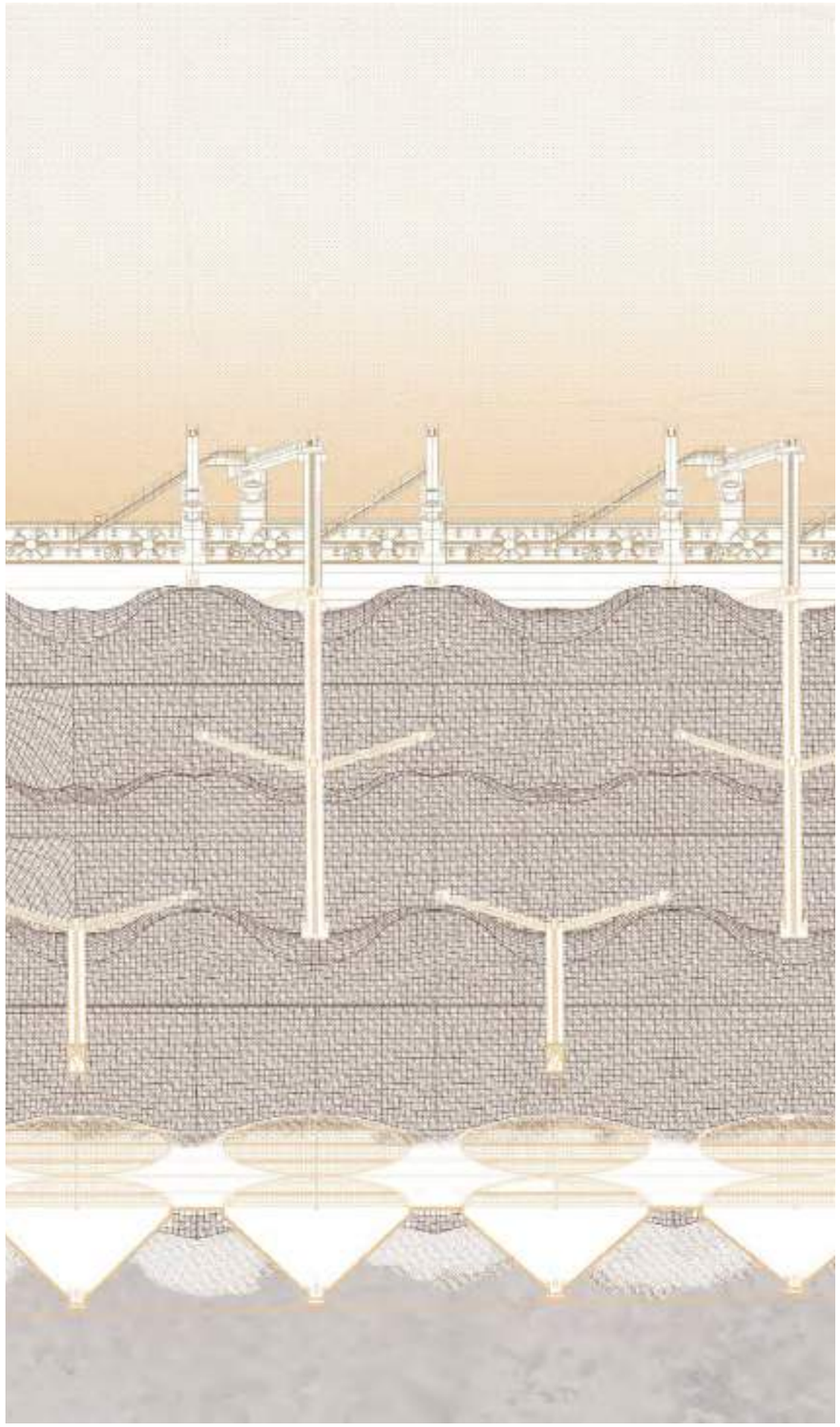


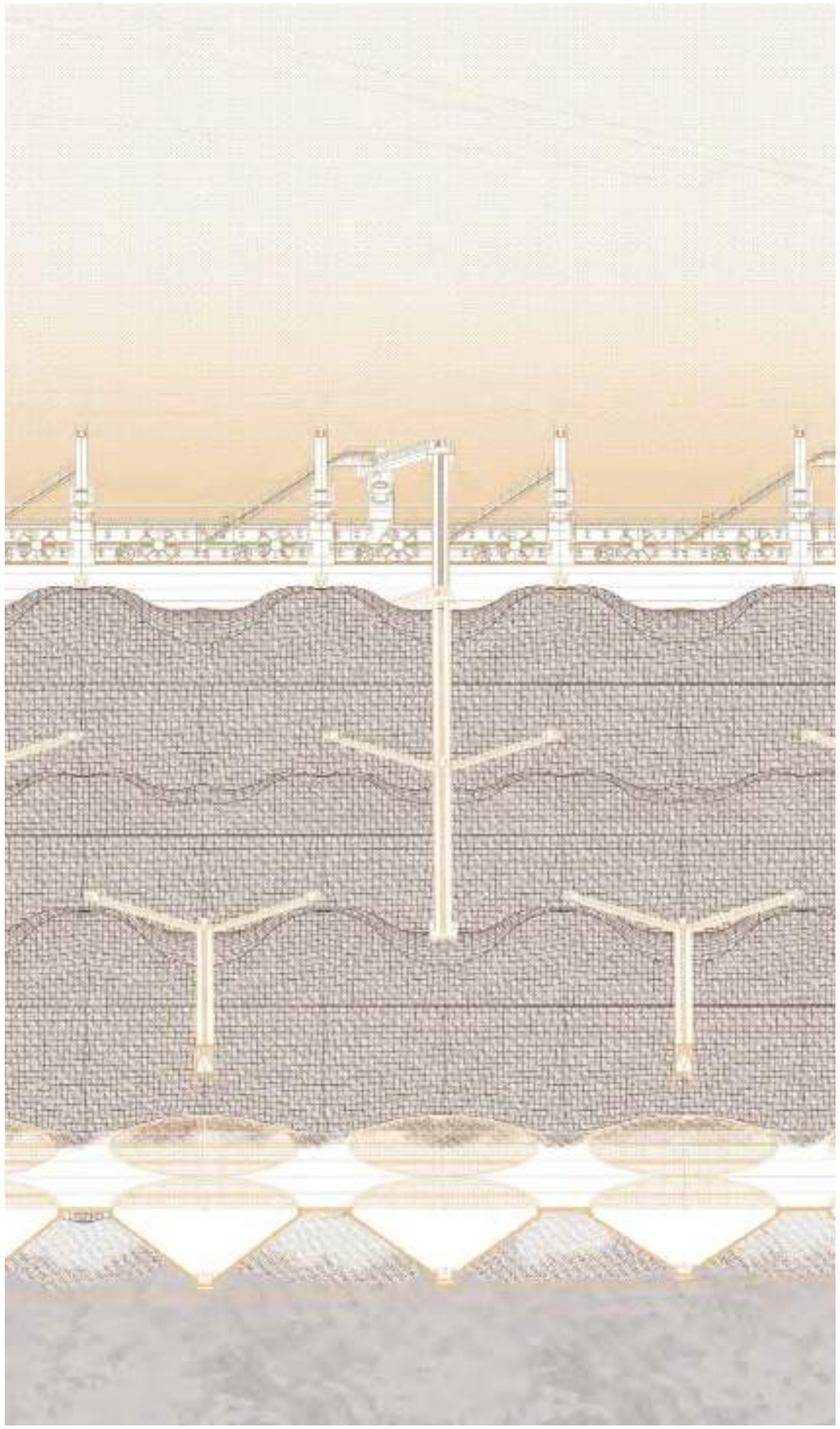
1B. [Opposite]
Precarious Dunes. Computer generated drawing. Print. 1:250 on 594 x 1782mm.

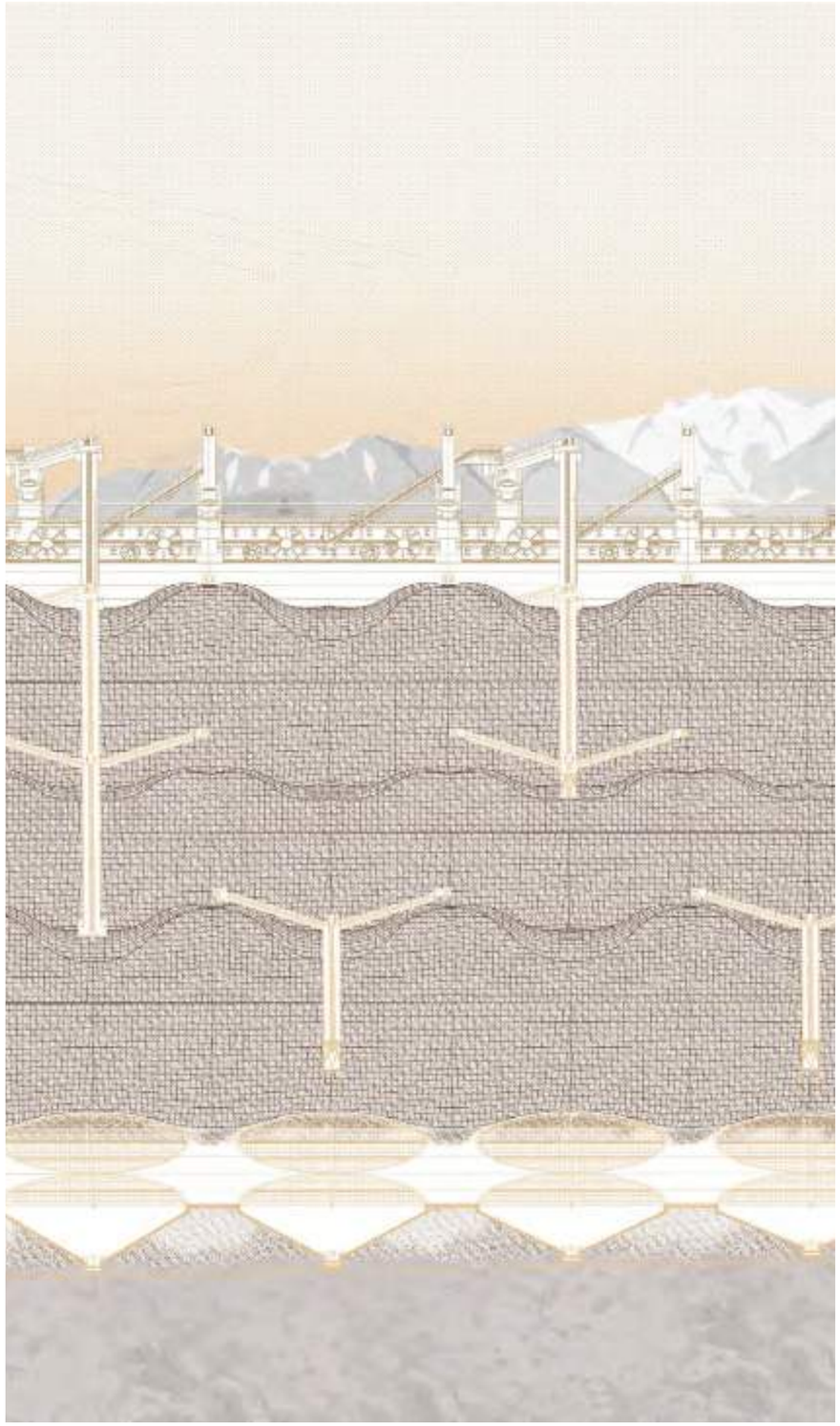
1A. [Previous Spreads]
The Leaky. Computer generated drawing. Print. 1:250 on 841 x 1189mm.

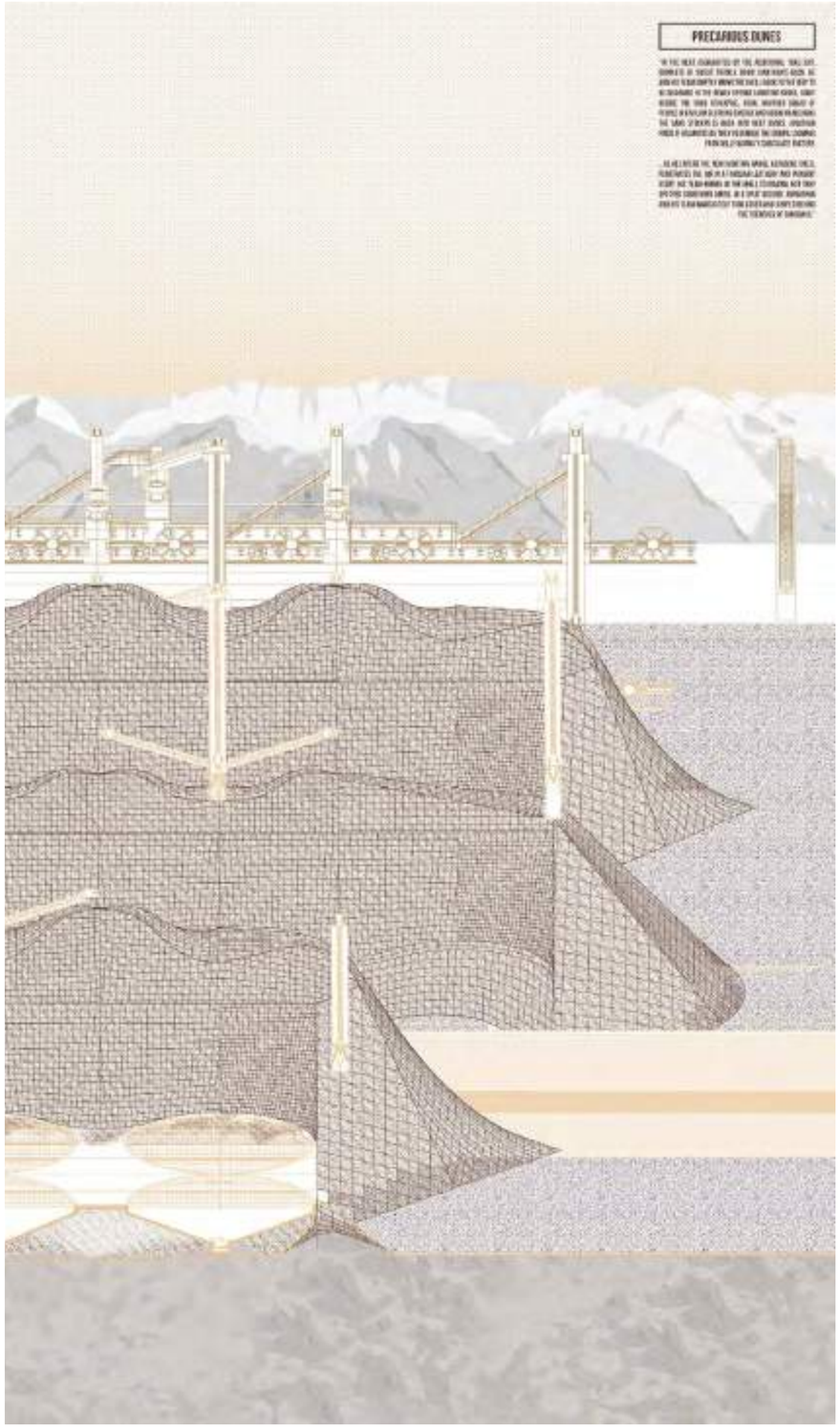
Like a new landscape dug out of sand, the range exaggerates the use of sand as a soft barrier for shooting sport. In return, the enormous scale of the dunes acting as a protective wall must be maintained as it slumps with gravity over time. Built on medium-coarse compact sand, the dunes designed on a 50 degrees angle of repose greatly exceeds the 34 degrees limit due to spatial constraints on site and the programmatic height requirements. Amidst the thrills and risks of a shooting range, the wall leaks. Grains of sand slumps from the wall and filters into the funnel underground – exposing our vulnerabilities as these large dunes deplete and overwhelm the shooters. By the 6th month, the new landscape underground formed from the leaked sand above act as a paintball arena. As sand depletion reaches a dangerous level by the 11th month, the range is closed for maintenance – to manicure these sand back into shape.

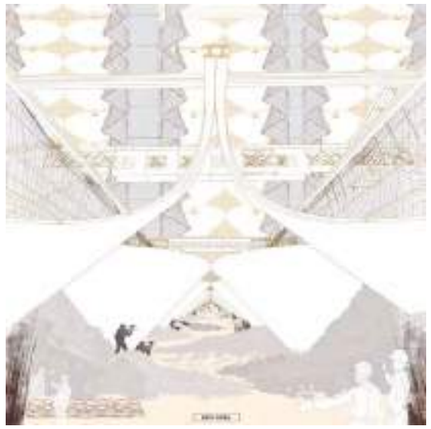









PRECARIOUS DUNES

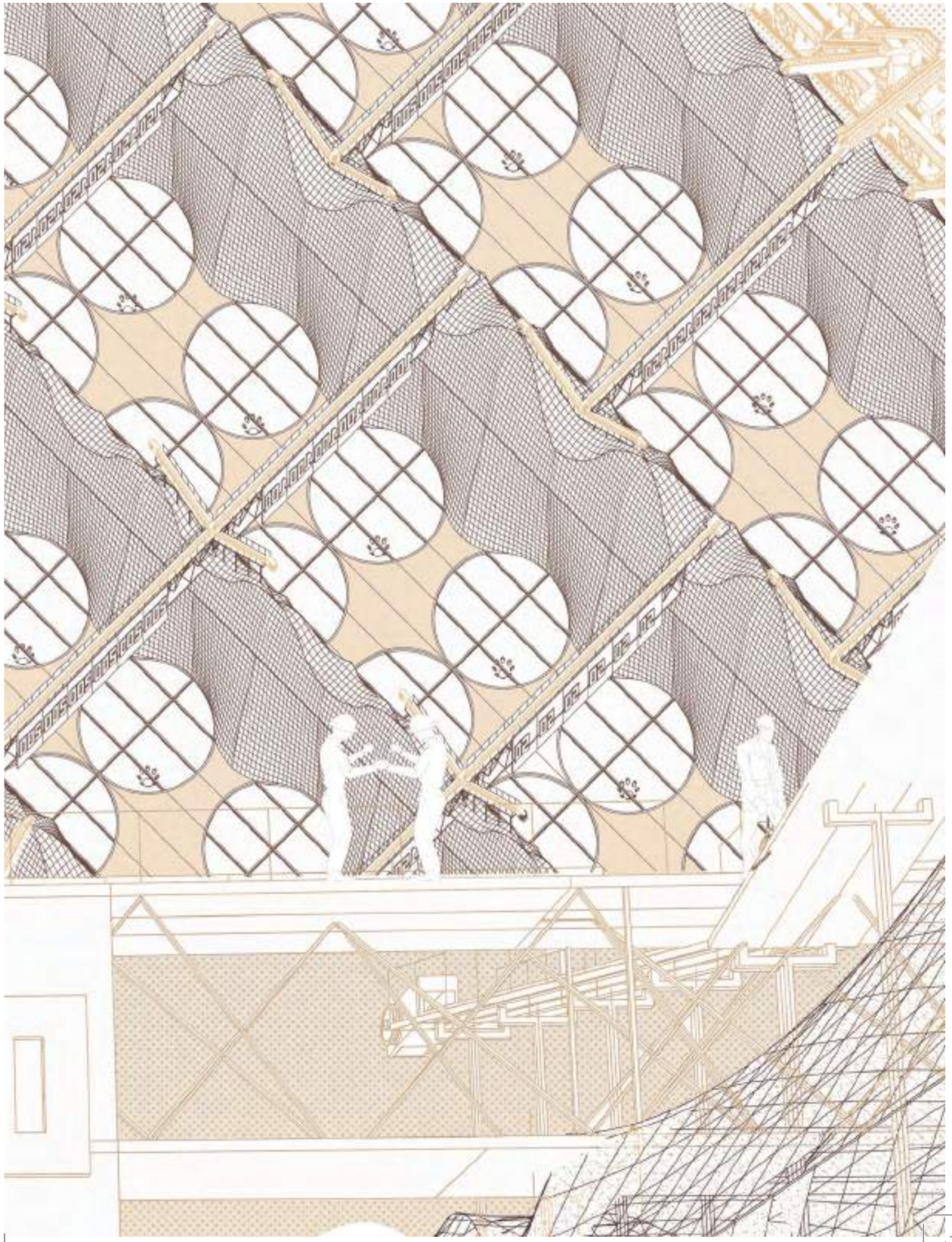


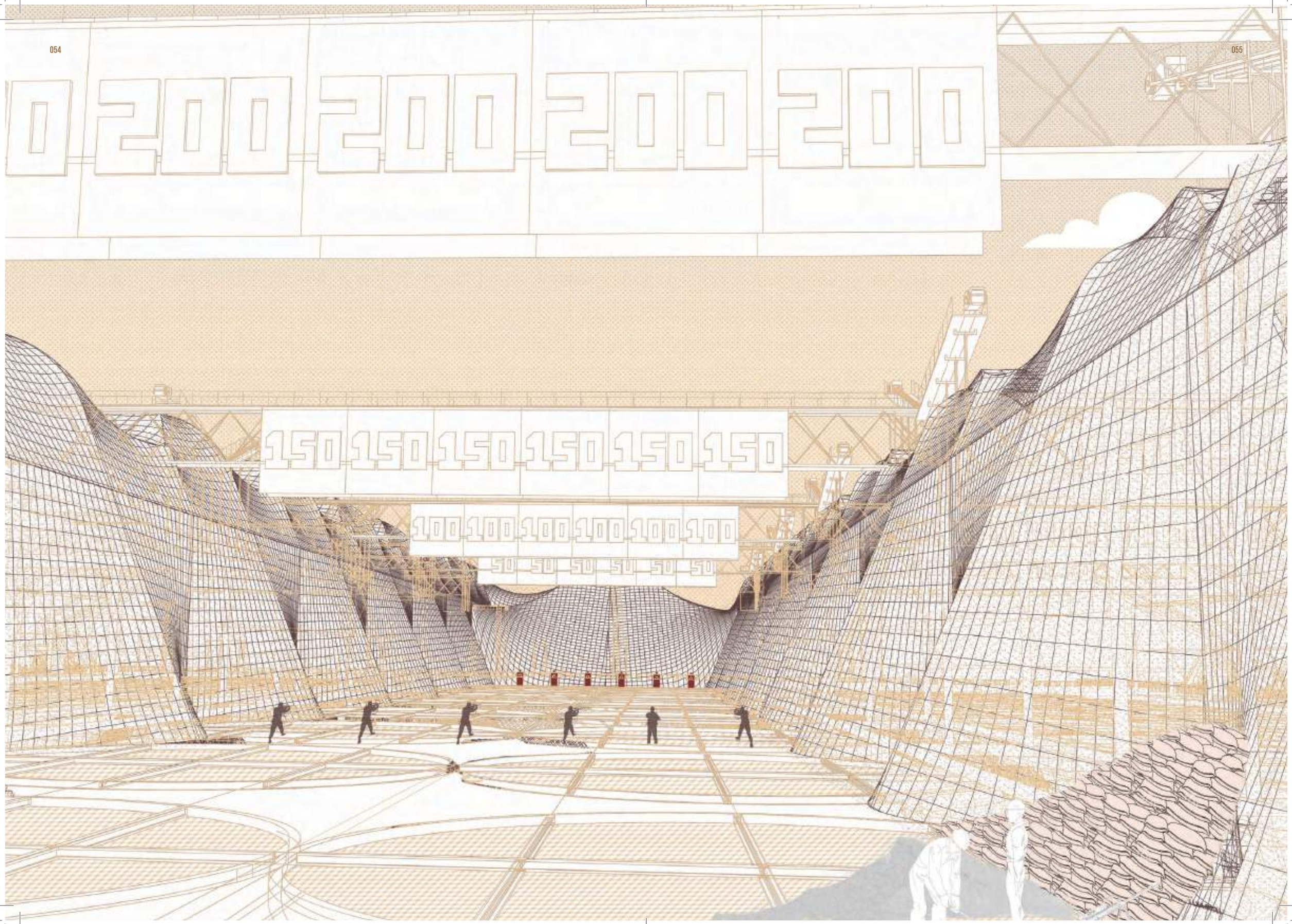
Top - Bottom

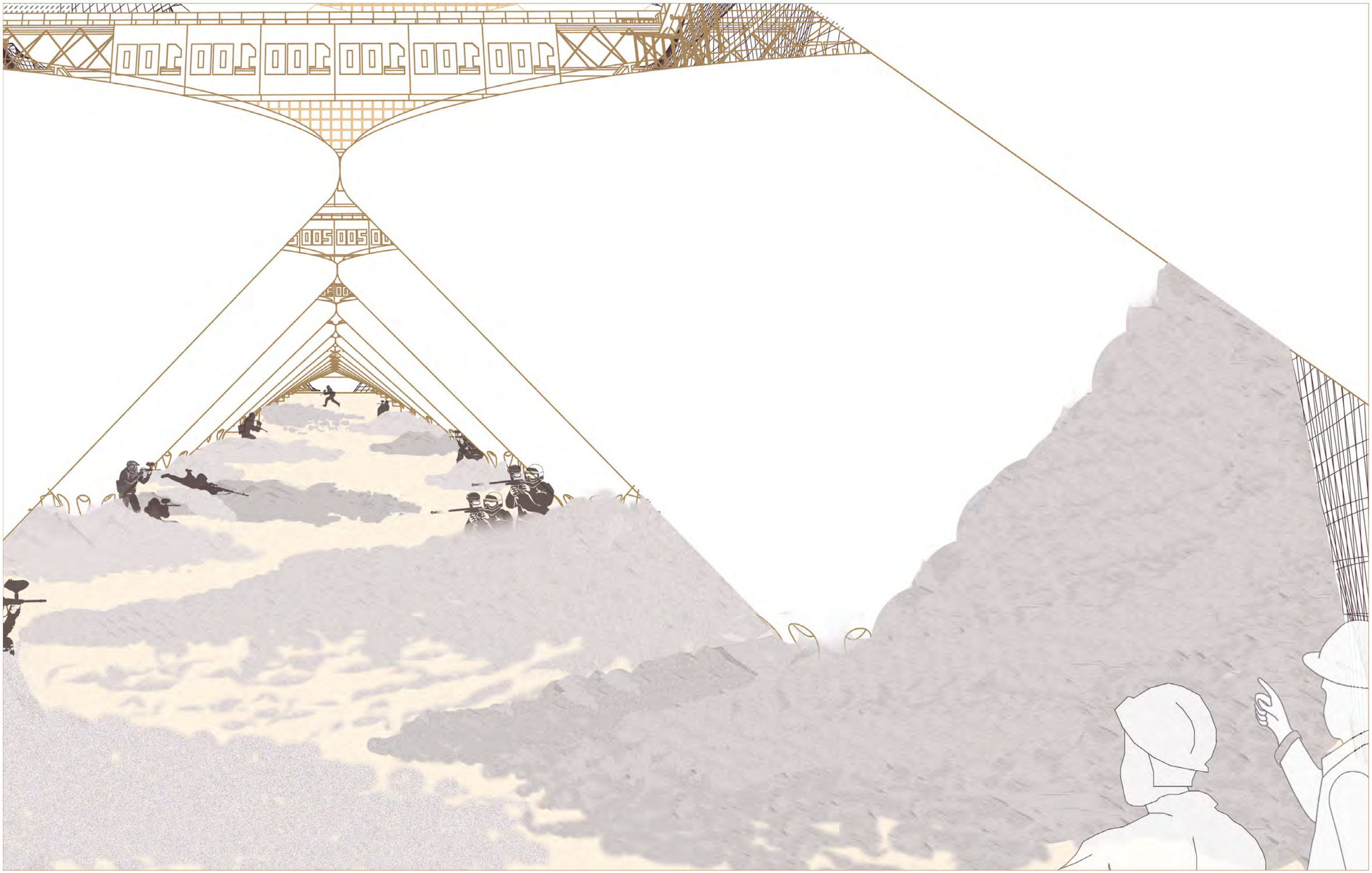
1C_1. Month 3 - Marksman. Computer generated drawing. Print. 594 x 594mm.

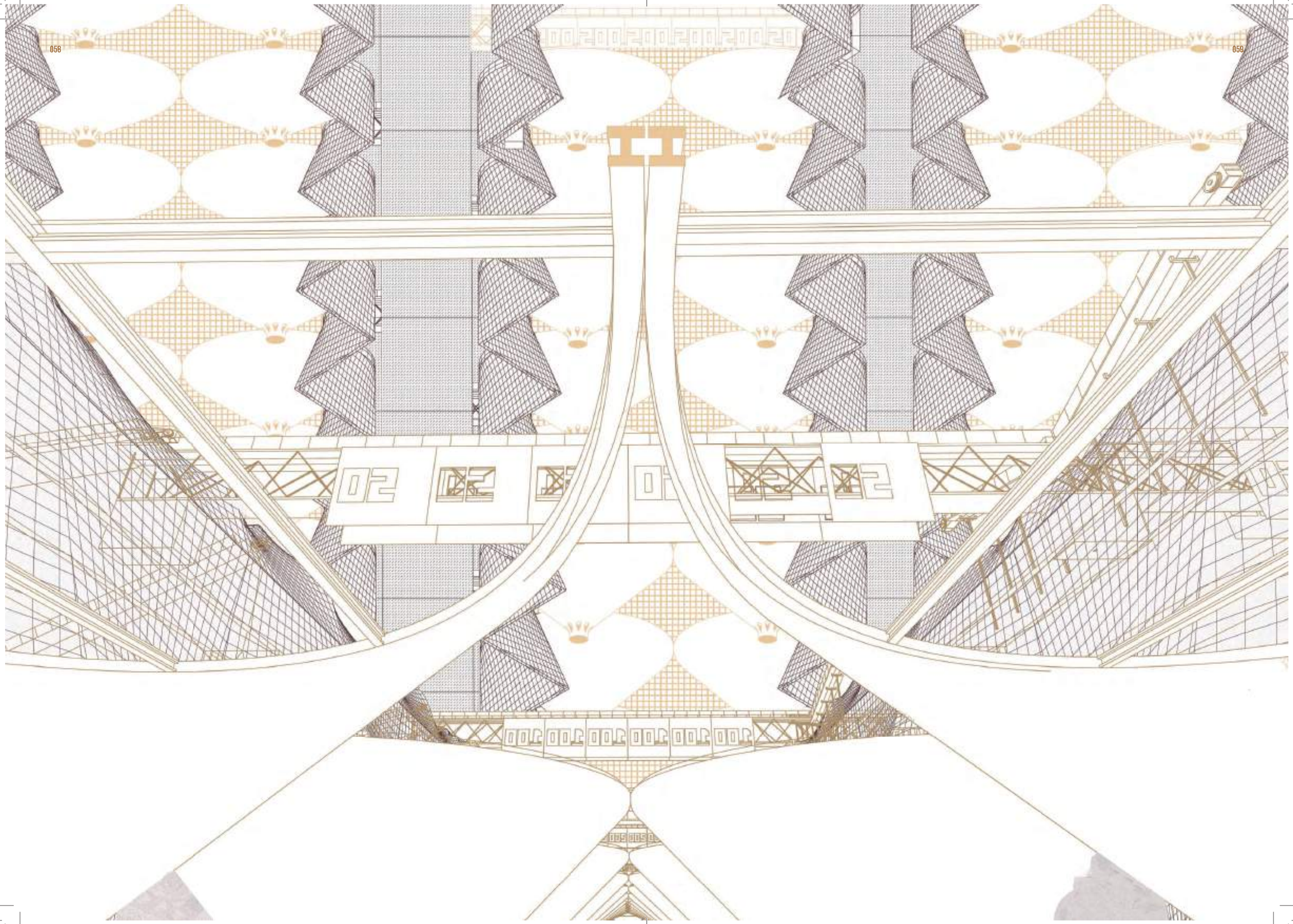
1C_2. Month 6 - Paintball. Computer generated drawing. Print. 594 x 594mm.

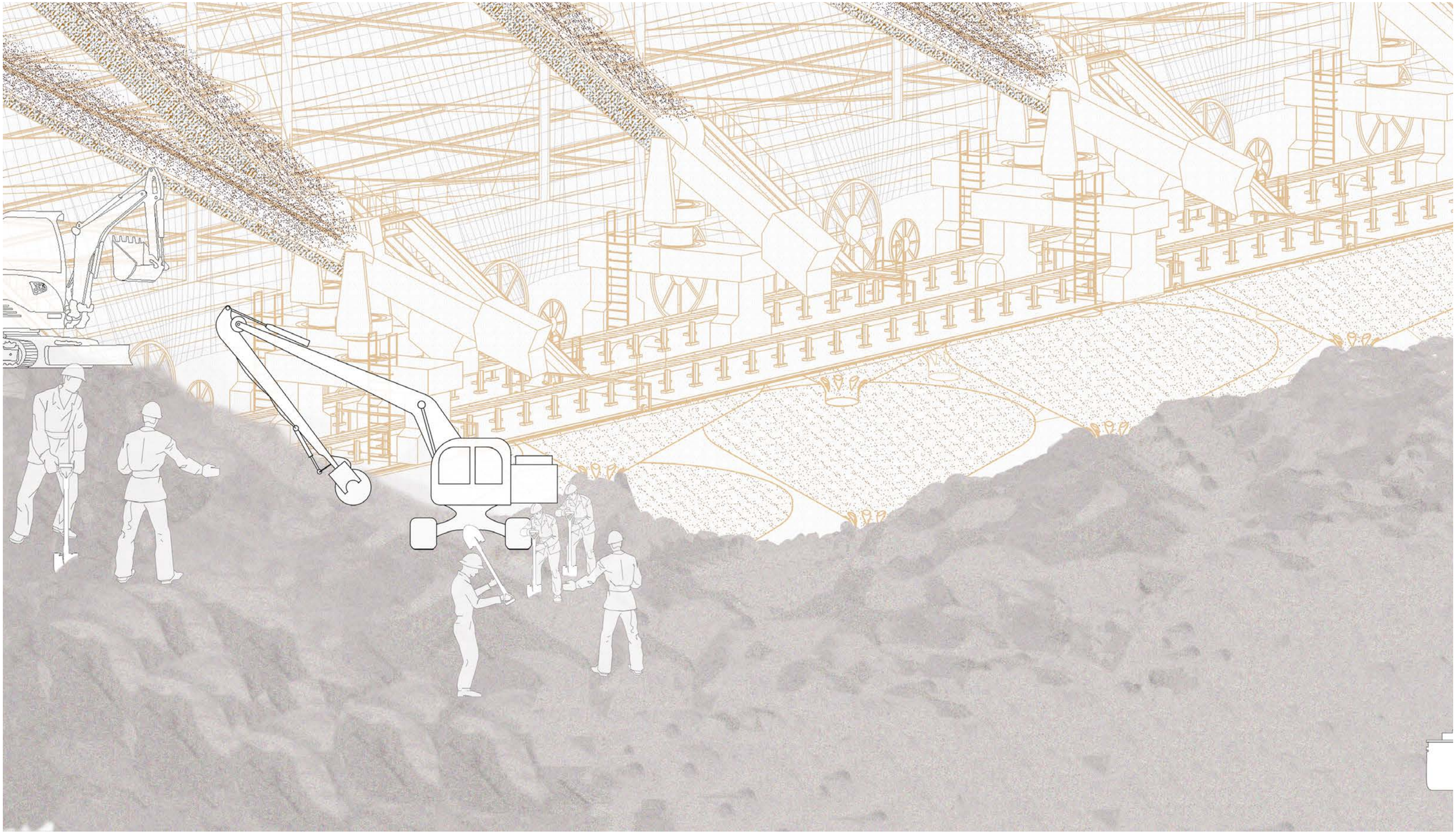
1C_3. Month 12 - Maintenance. Computer generated drawing. Print. 594 x 594mm.



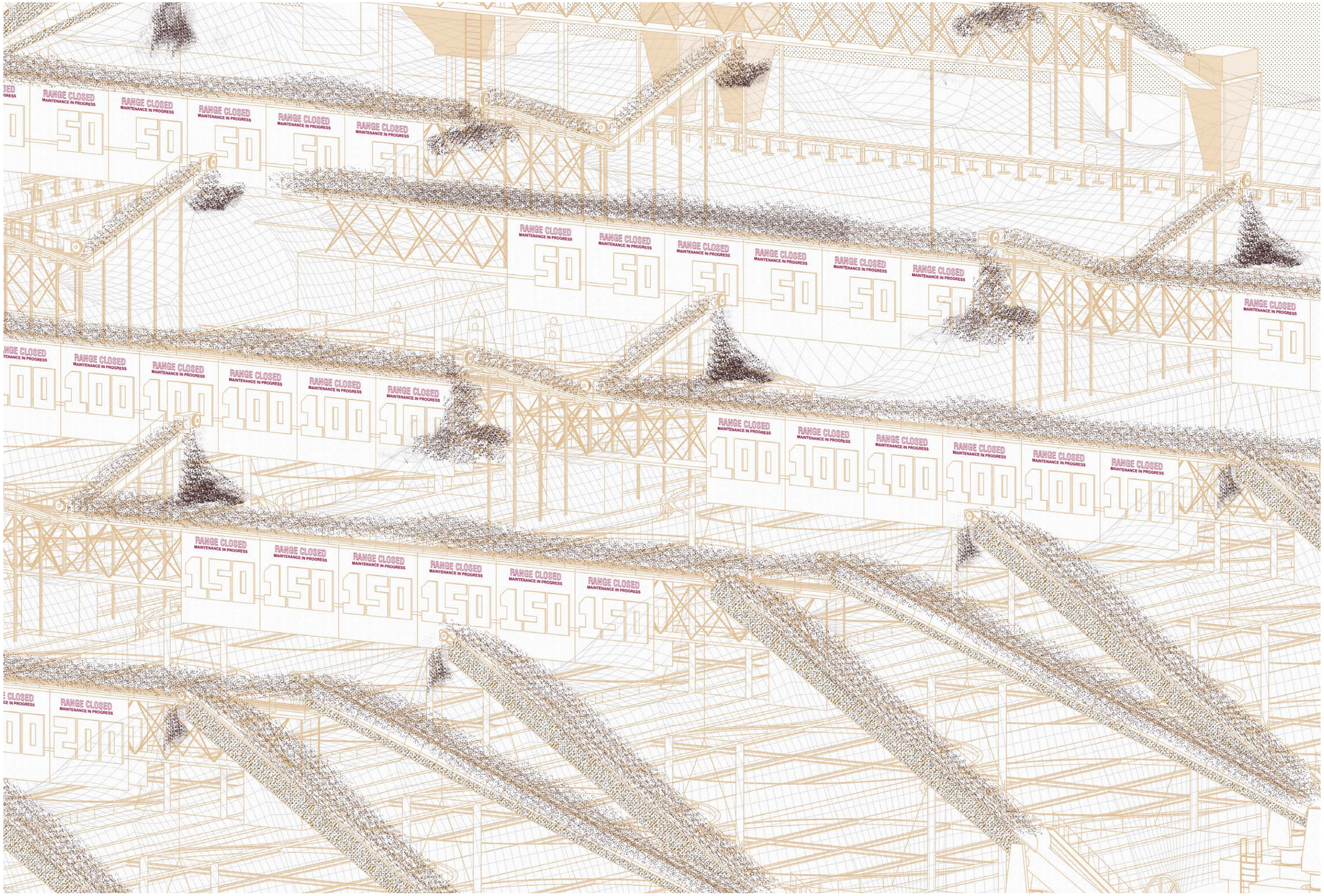

200 200 200 200 200 200
150 150 150 150 150 150
100 100 100 100 100 100
50 50 50 50 50 50

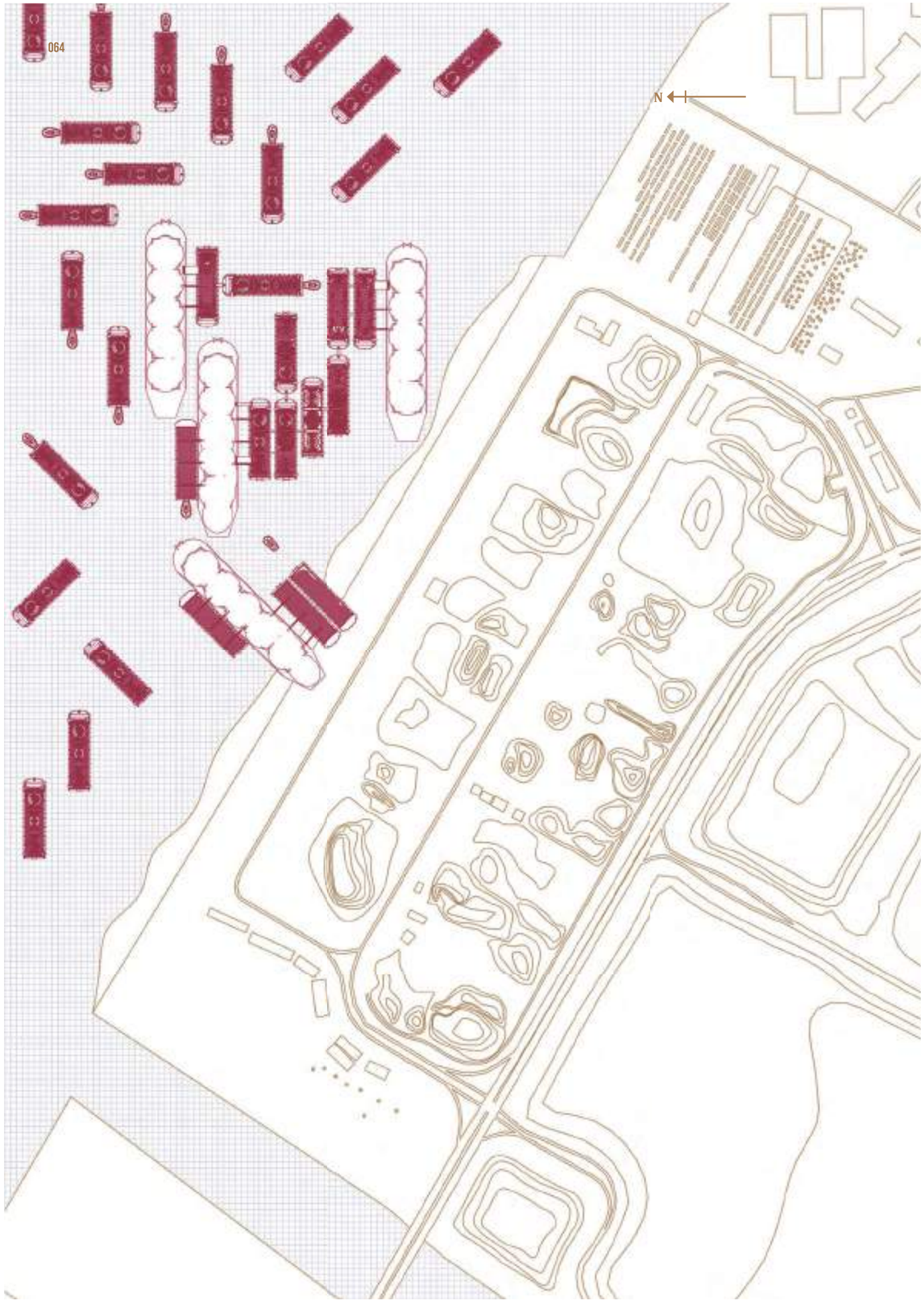






Month 12 - The range is left with the standing mesh structure, while the underground paintball arena is completely buried in sand.


RANGE CLOSED
MAINTENANCE IN PROGRESS
50
100
150
200



DP001. Punggol Intervention. Scale [1:5000 on an A4]

DP002. [Overleaf] **Barge Pattern.** Scale [1:500 on an A4]

[Stockpile] Storage of sand, imported and/or extracted material matter.

[Archipelago] An extensive group of is**lands**. Good for pirate hideouts.

[*Super Archipelago*] A series of sand barges transformed into a round-island travelling cruise and night club.

Club
Dancing Bar
Casino
Nudist Beach
Buffet Restaurant

THE ARCHIPELAGO

Punggol | Barge Cruise

CONCEALEMENT X HEDONISTIC PLEASRURES

THE FLAMBOYANT

PINGGOL BARGE CRUISE – SUPER ARCHIPELAGO

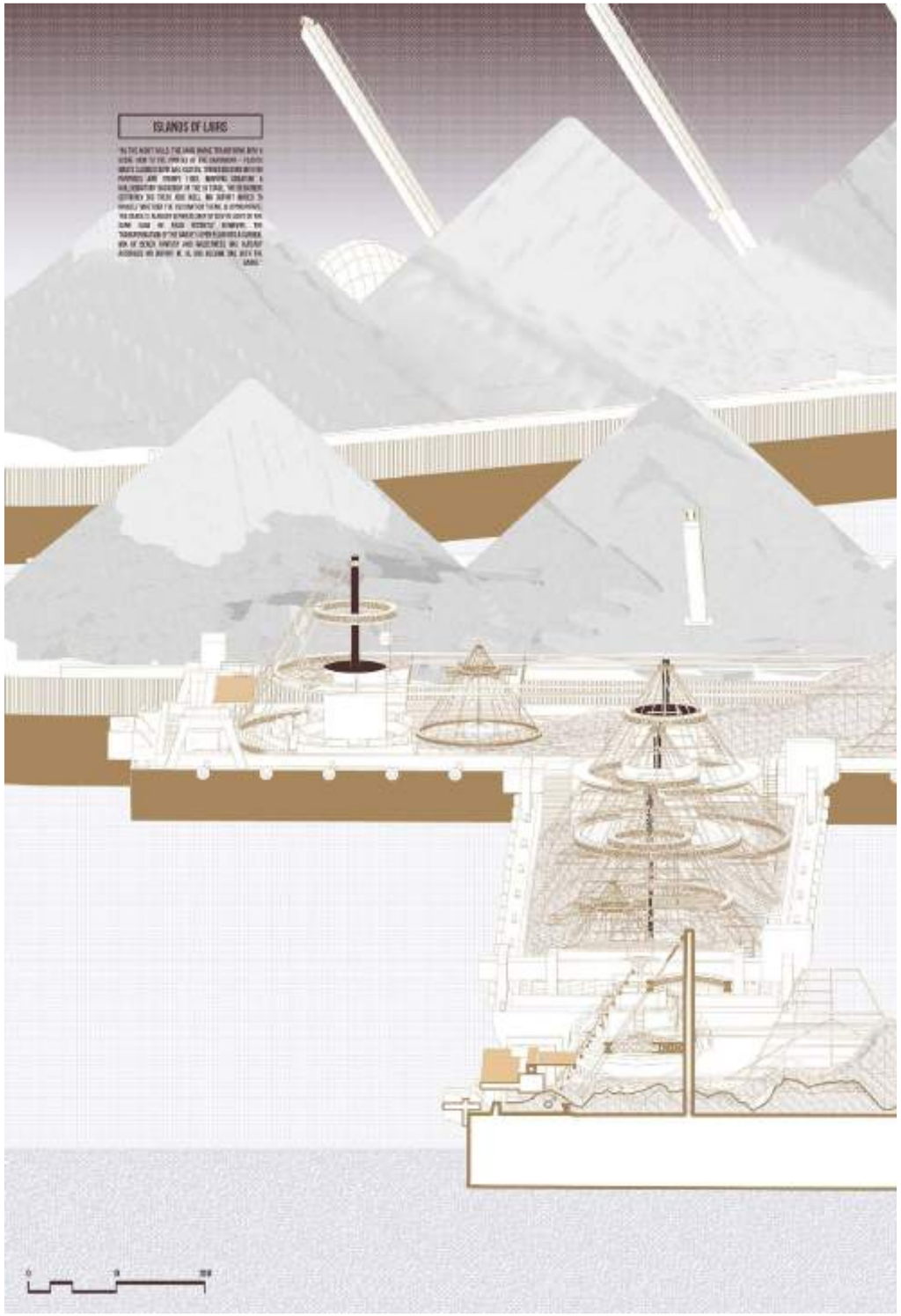
THE SAND IS HALF-EMPTIED, THE LIGHTS ARE LOW, AND THE SAILS ARE UP TO THE FULL MAST. IT IS HAPPENING AGAIN JOIN US ON THE *SUPER ARCHIPELAGO* TO HAVE A CLUB EXPERIENCE LIKE NO OTHER. SECLUDED OFFSHORE FROM PULAU PINGGOL, TIMOR, ENORMOUS PILES OF SAND REVEAL A NEW ISLAND PARADISE ON A SERIES OF SAND BARGES. MUSE YOURSELF TO A THEATRICAL ENSEMBLE OF DANCE FLOORS, BARS, CASINOS AND NUDIST BEACHES AS YOU EXPLORE THE VARIOUS ISLANDS AND AMENITIES ON BOARD. PARTY THROUGH THE NIGHT WITH WORLD-CLASS DJS ON THE FLOATING BEACHES AND TAKE ON MASSIVE SANDHILLS IF YOU DARE. FROM 9 PM TO 6 AM, *SUPER ARCHIPELAGO* EMBARKS ON AN ODYSSEY AROUND THE ISLAND OF SINGAPORE. AS YOU SIP ON CHAMPAGNE AND EXPERIENCE THE IMMERSIVE SUNRISE OVER THE HORIZON TOWARDS THE END. LIMITED TIME, BY INVITATION ONLY.

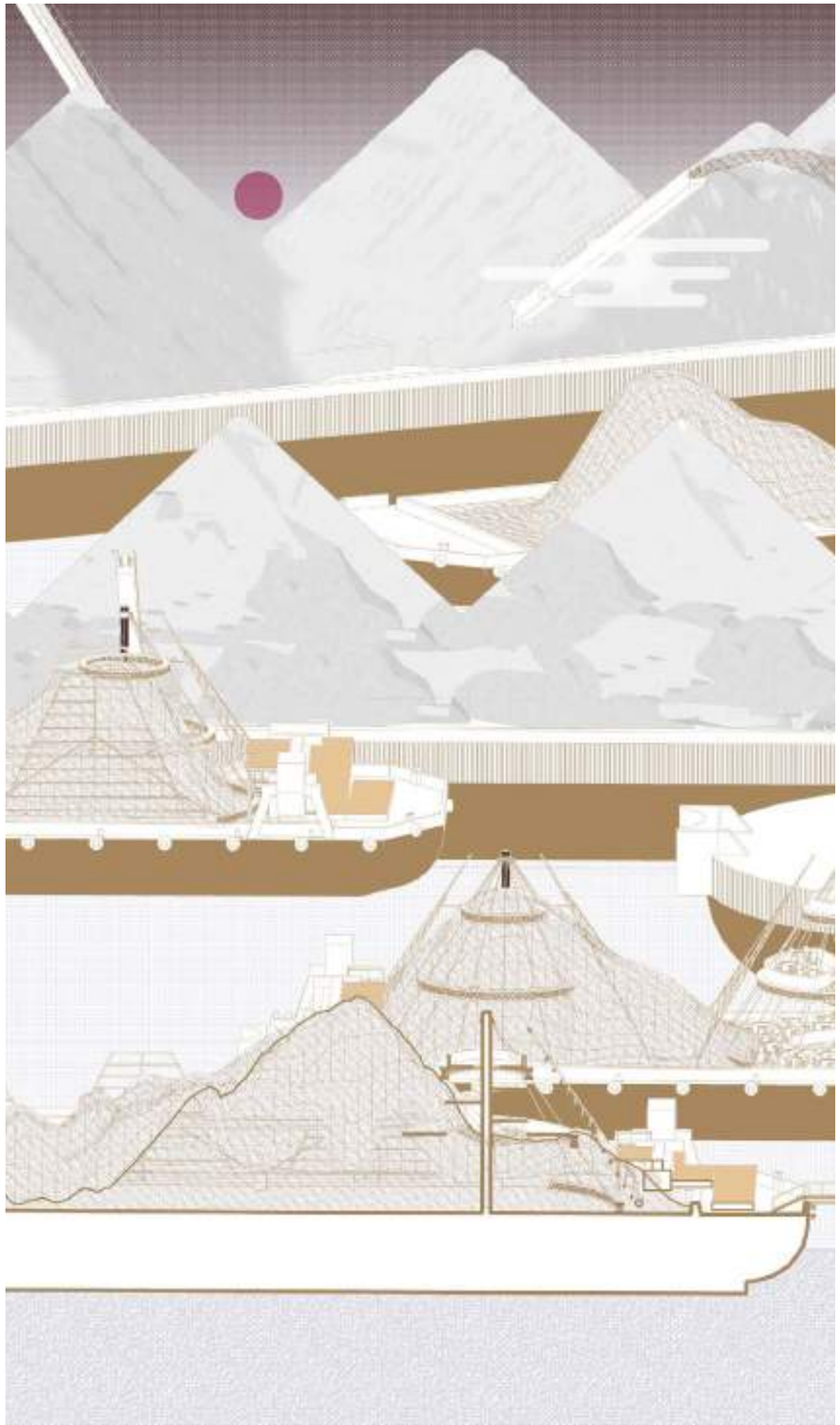

THE FLASHPOINT

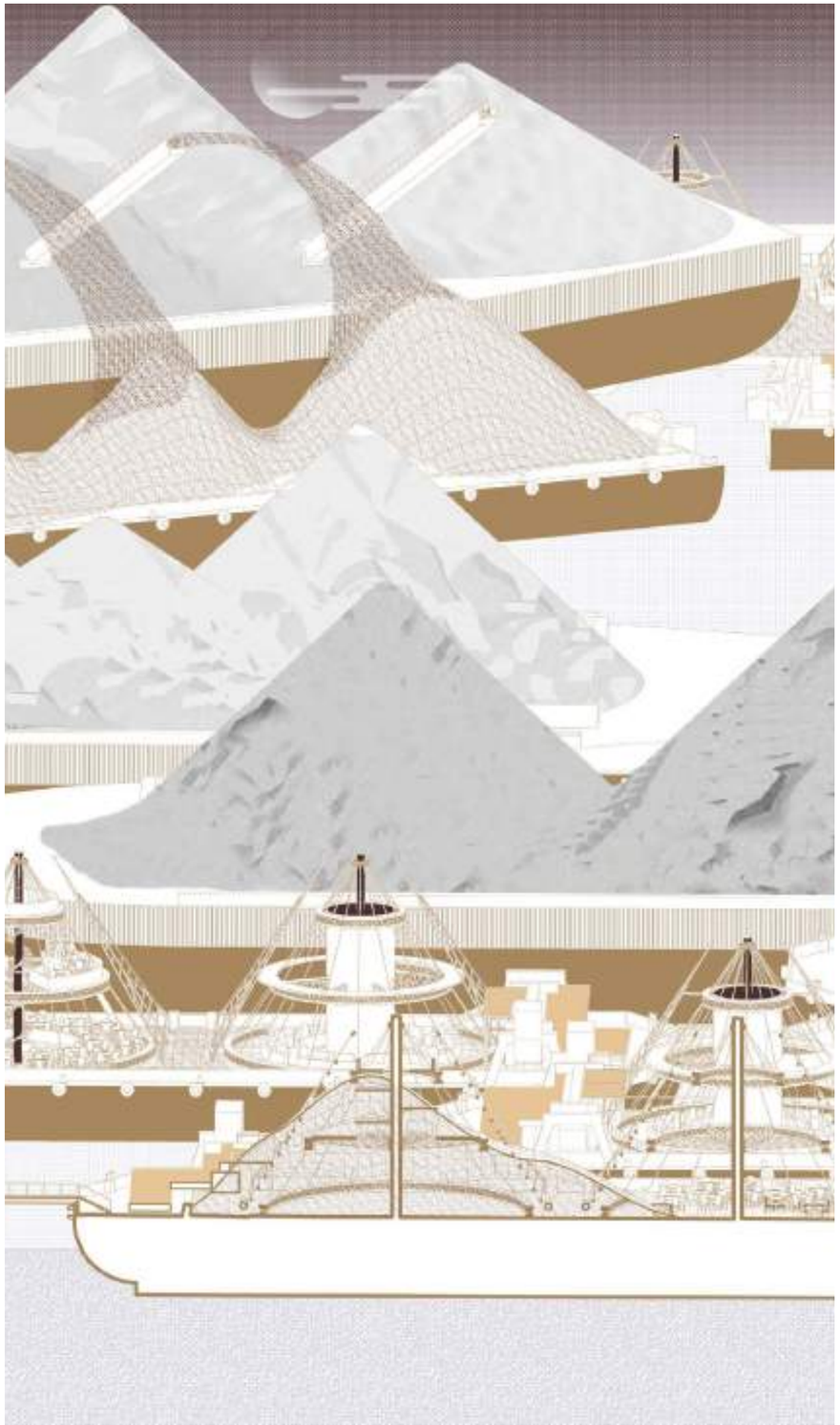
2B. [Opposite]
I**slands of Lairs.** Computer generated drawing. Print. 1:250 on 594 x 1782mm.

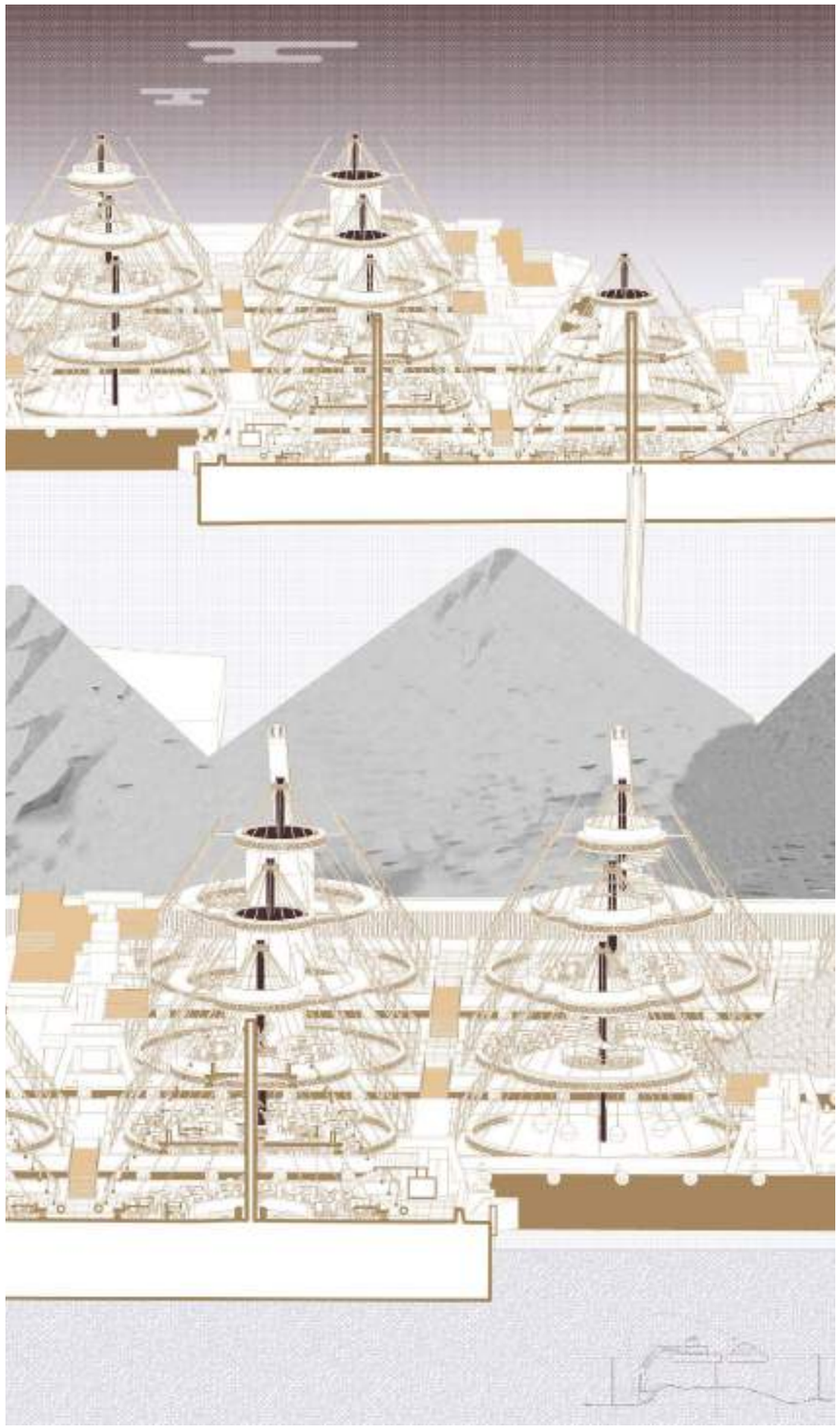
2A. [Previous Spreads]
The Flamboyant. Computer generated drawing. Print. 1:250 on 841 x 1189mm.

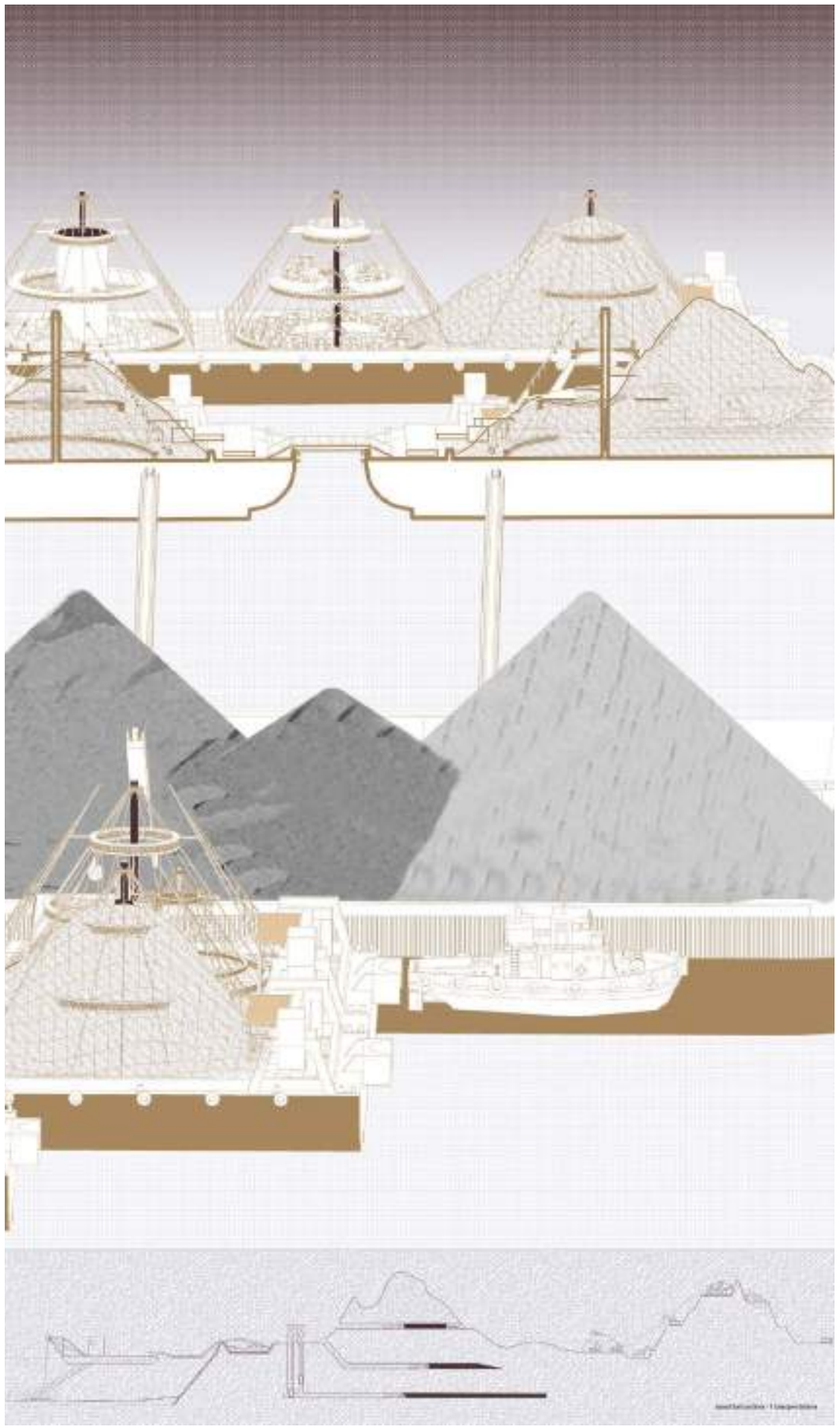
Drifting off Punggol Waterfront, each sand barge transforms into a temporary utopia of floating island using a series structural kit-of-parts. Mimicking the image of fully loaded sand barges observed from afar, the structures house various party programmes and double as a functional angle retainer. Like a multiplying landscape which permutates differently every day, the sand barges connect to each other via bridges and hide away from direct view. Threading on the borderline of law, sand becomes concealment for the activities hosted on board. As the party ball drops in the evening, sand's flamboyance transforms from a scarce circulated resource, into an excessive hedonistic matter where clubbers frolic in, climb, and party in sand showers. Sailing off from BCA's Punggol Aggregate Terminal, the barges travel around the island – instead of transporting sand like in the day, it is a parade around the constructed skyline of Singapore, built on sand.









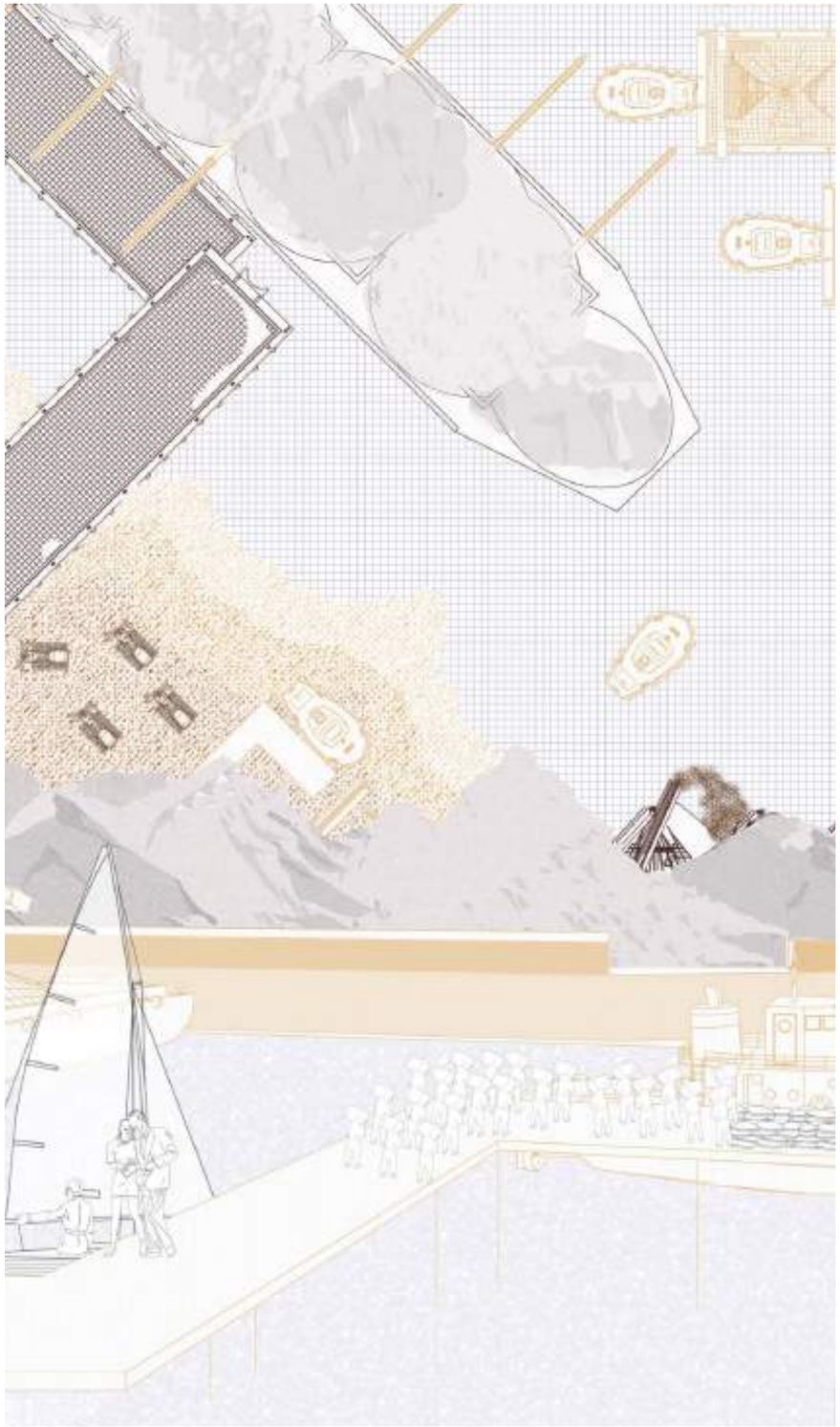


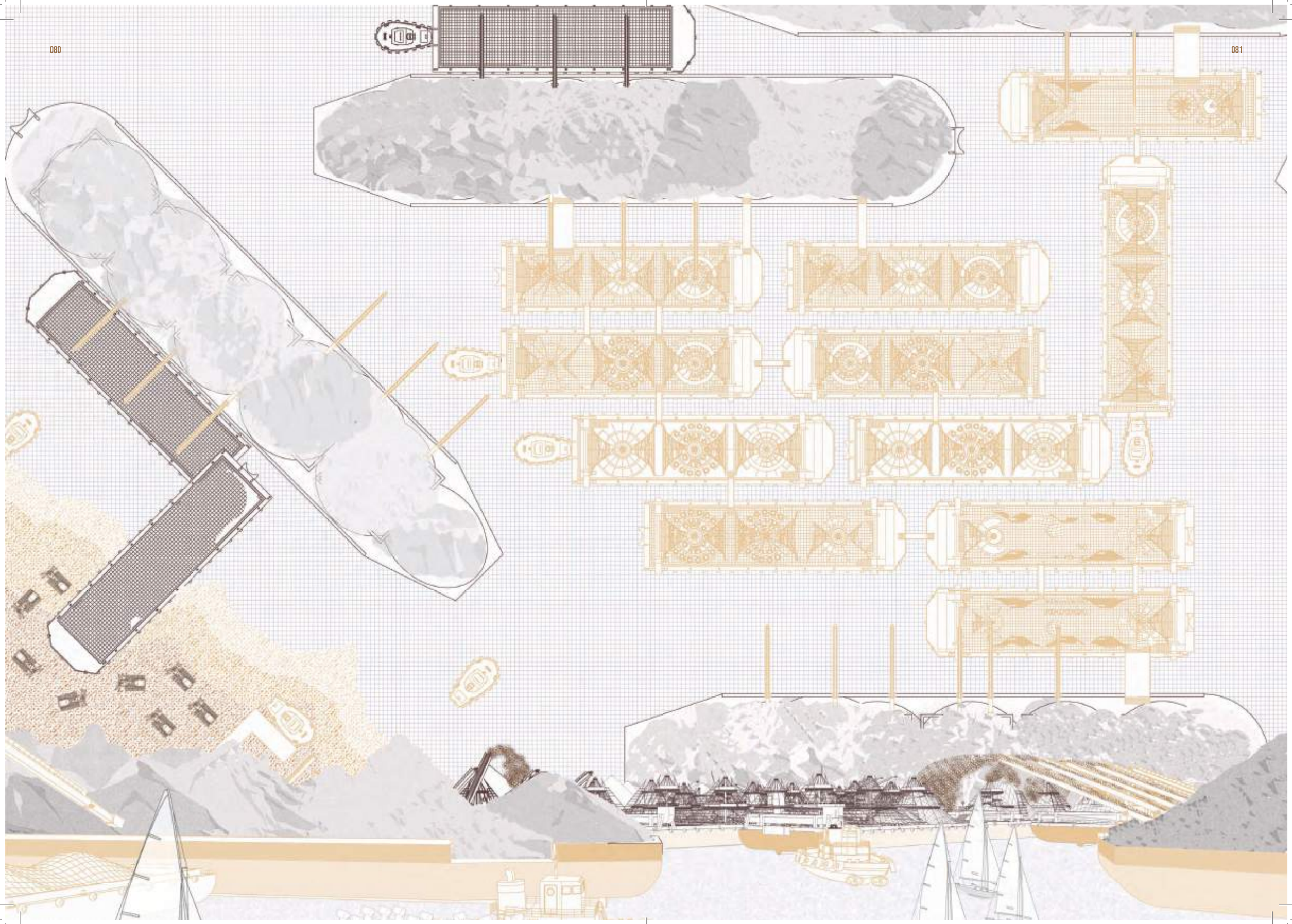
Top - Bottom

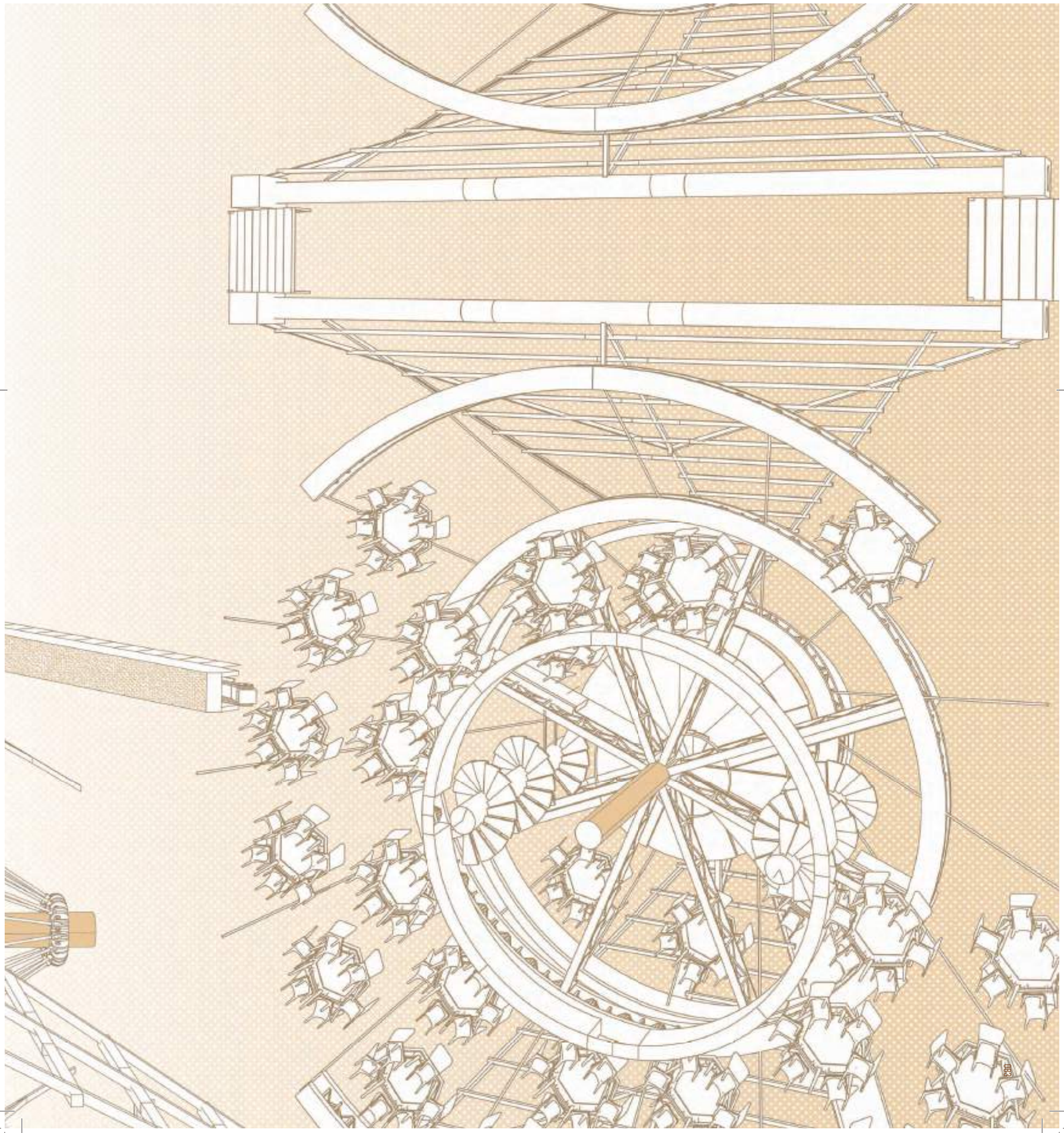
2C_1. 6pm - Embarkment. Computer generated drawing. Print. 594 x 594mm.

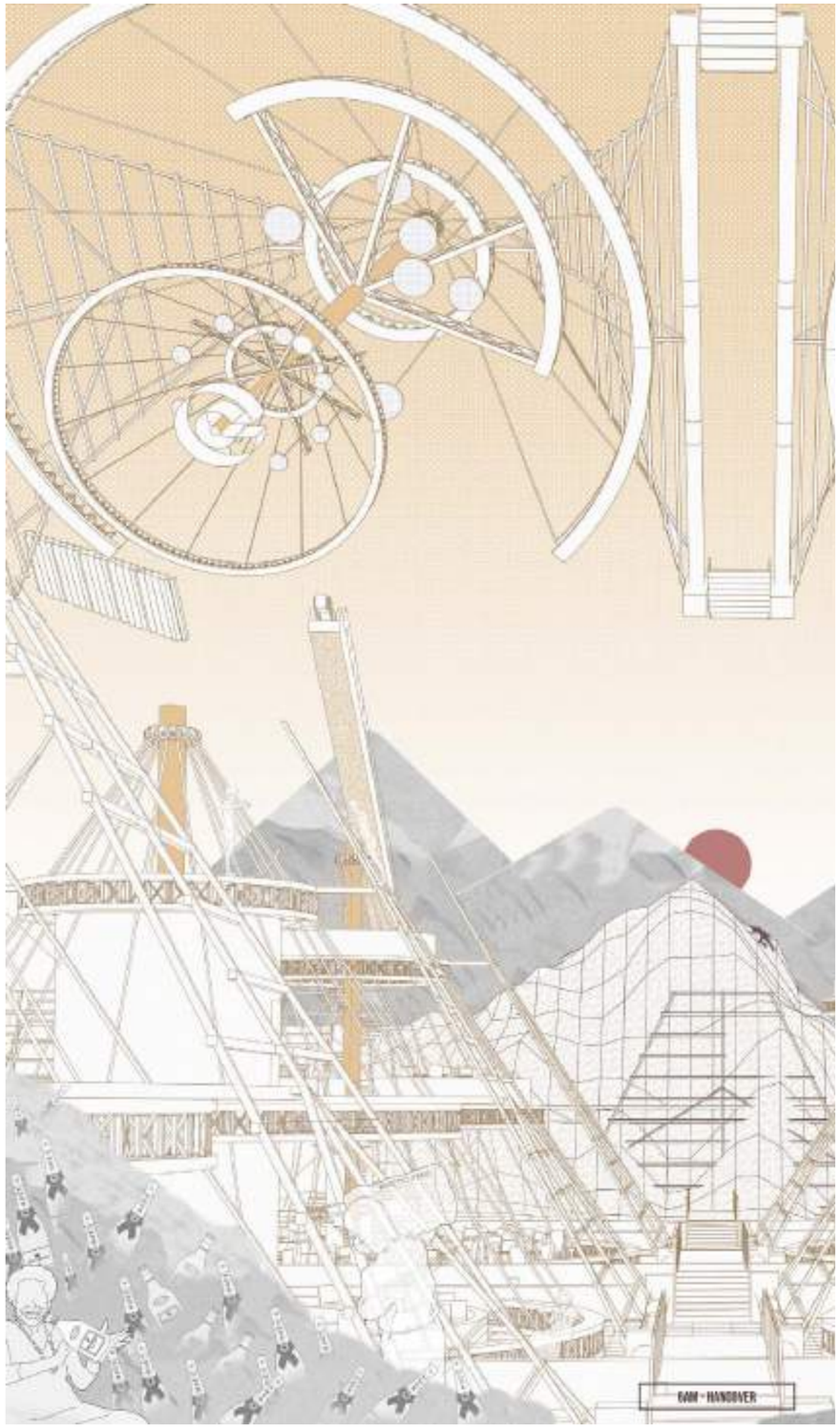
2C_2. 6am - Hangover. Computer generated drawing. Print. 594 x 594mm.

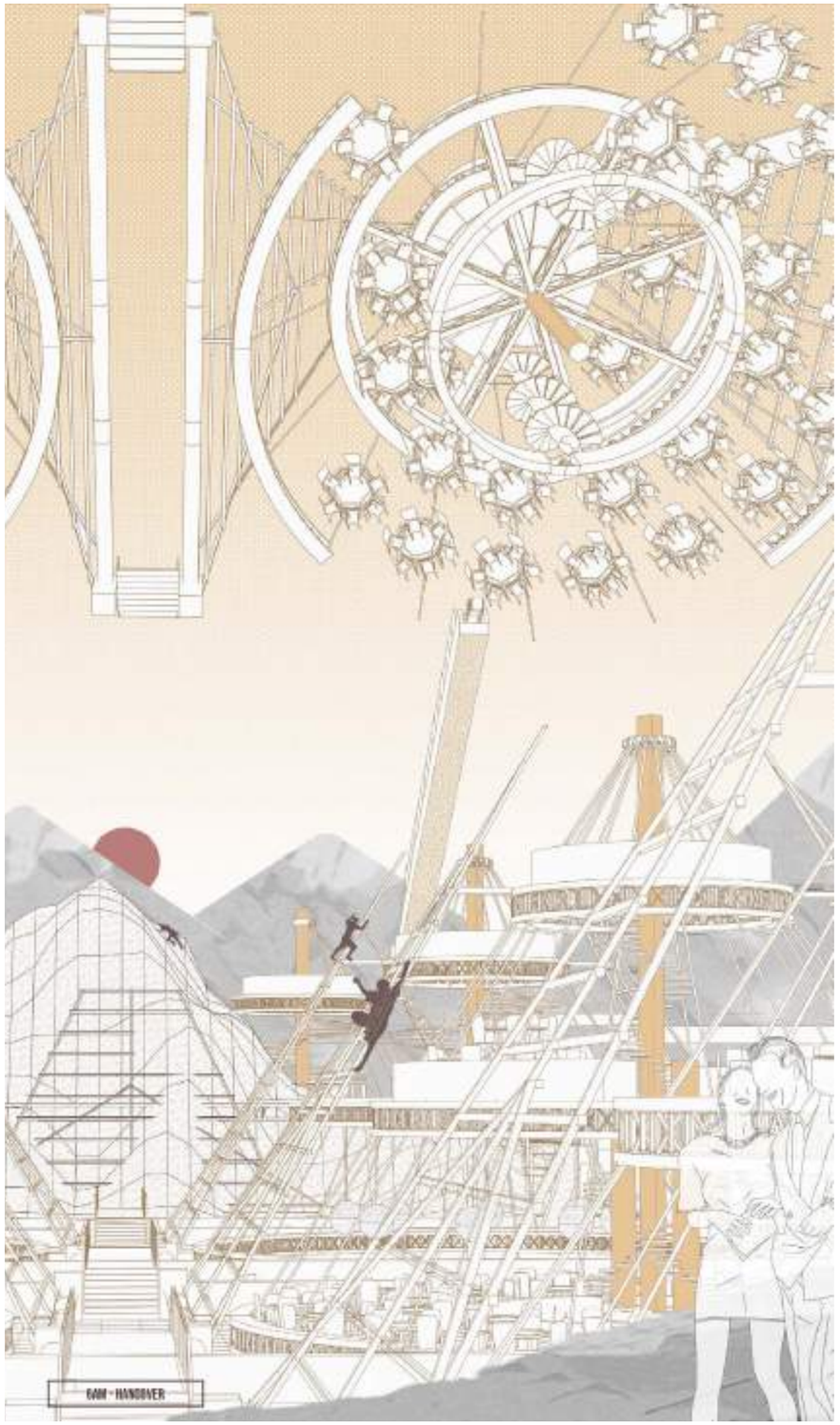
2C_3. 12am - Hedonists. Computer generated drawing. Print. 594 x 594mm.



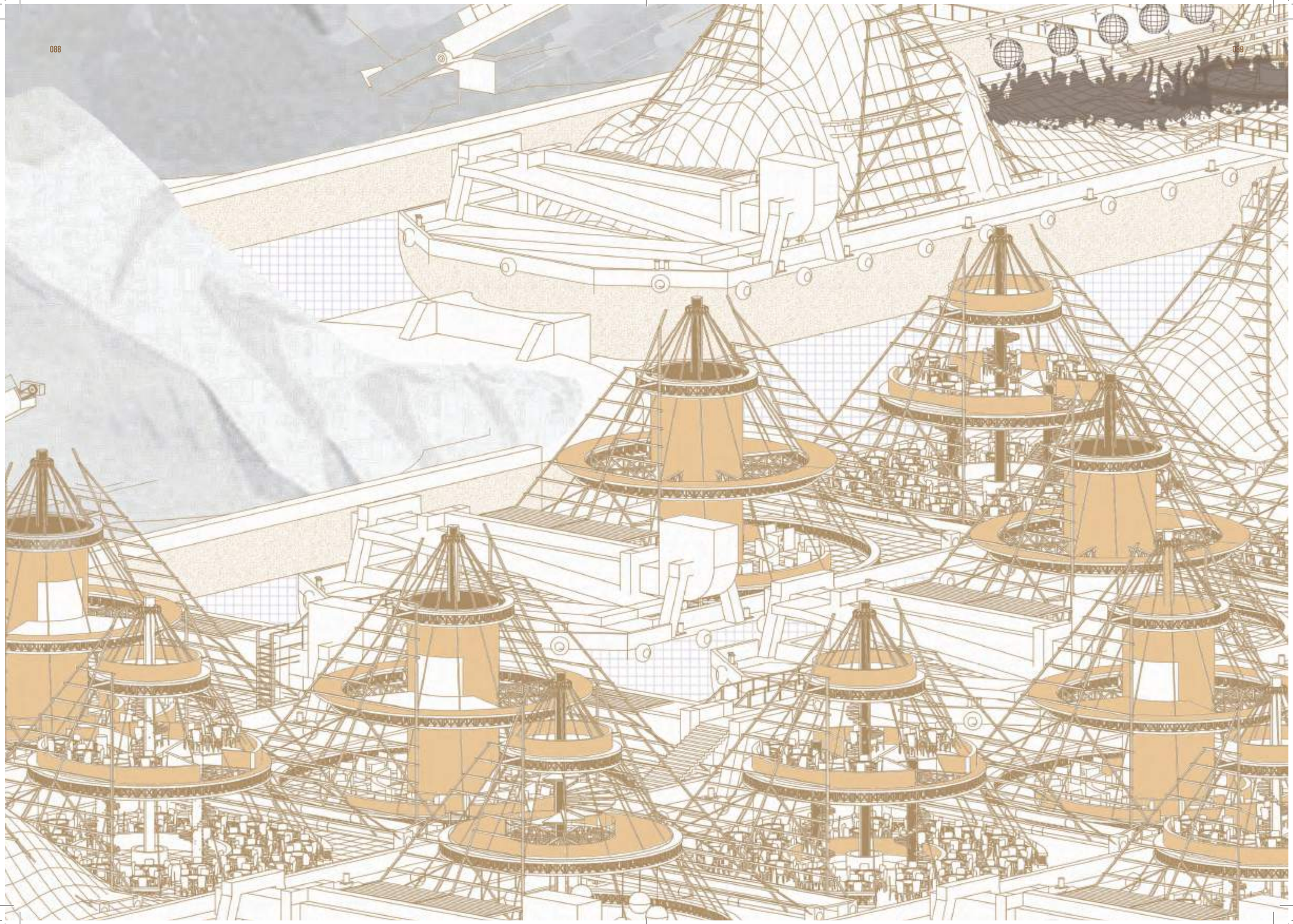





6AM - HANOVER


6AM - HANOVER

12am - The sand parade odyssey.



DT001. Tampines Intervention. Scale [1:5000 on an A4]

DT002. [Overleaf] **Beach Pattern.** Scale [1:500 on an A4]

[Stockpile] Storage of sand, imported and/or extracted material matter.

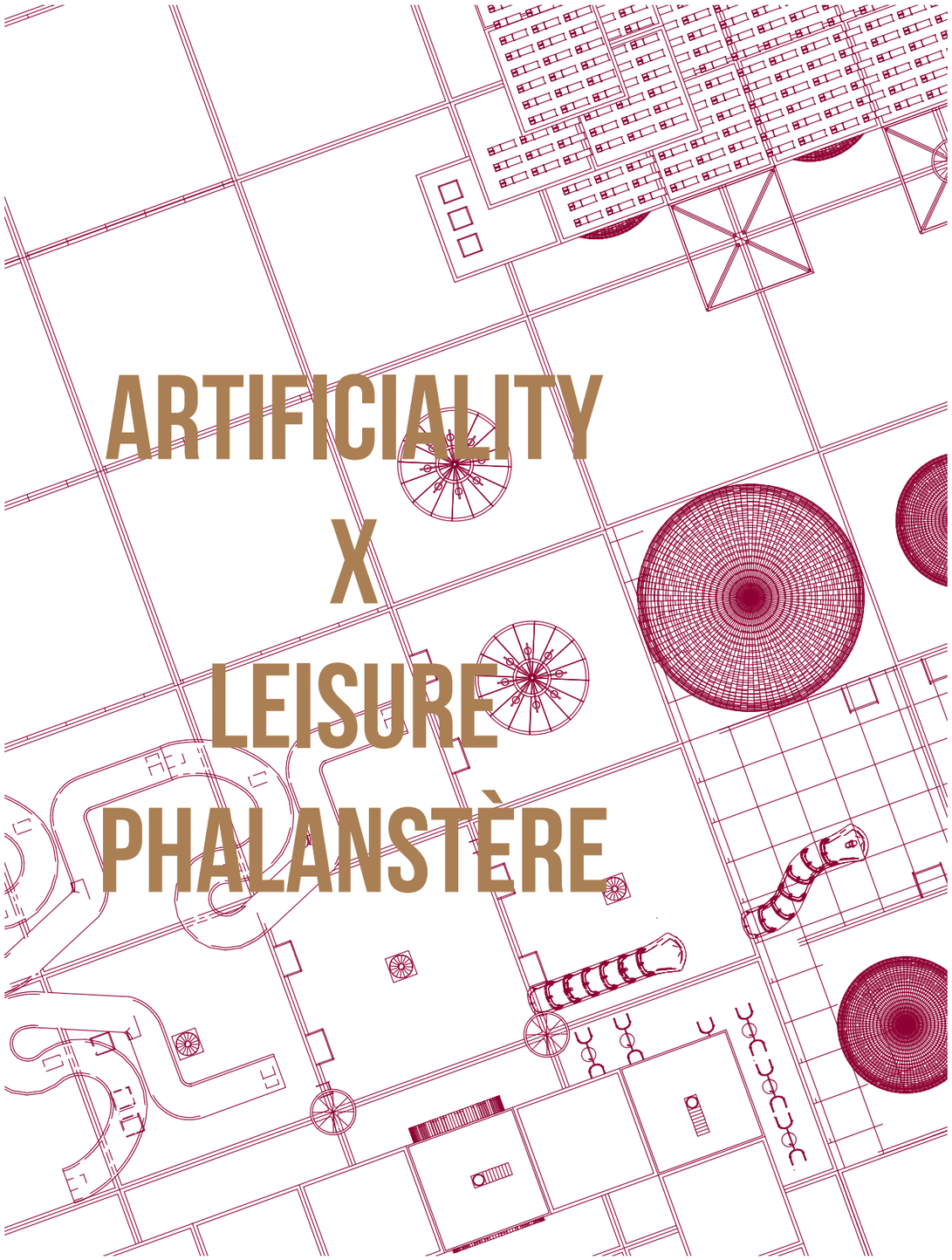
[Beach] A landform alongside a body of water which consists of loose particles.

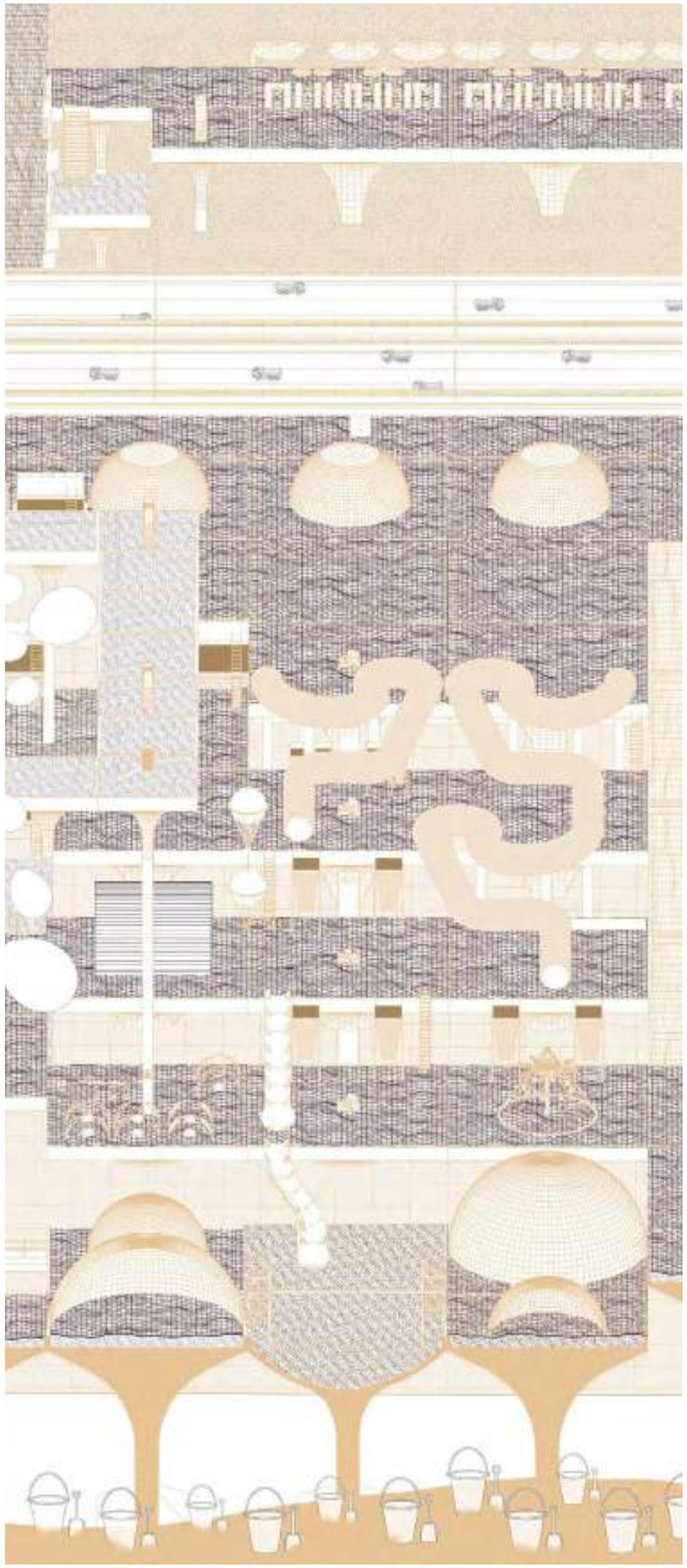
[*Super Beach*] An extensive infinity sand-pool that cantilevers over two reservoirs.

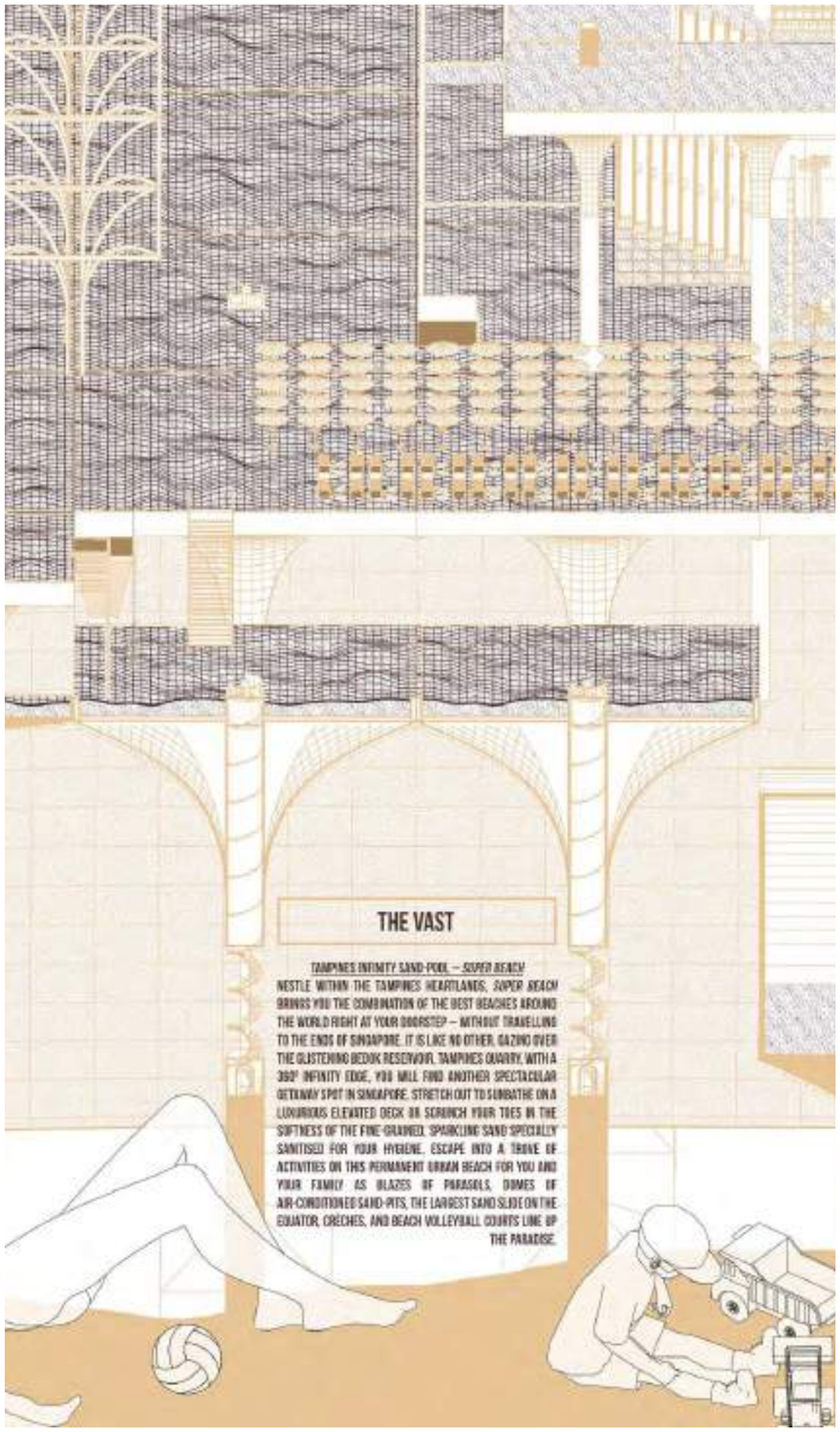
Beach Volleyball Arena
Children Crèche
Natural Sun Tan
Cliff Fishing
Sand Slide
Sandcastle Playground
Kayak & Dragonboat

THE BEACH

Tampines | Infinity Sand-pool







THE VAST

TAMPINES INFINITY SAND-POOL – *SUPER BEACH*

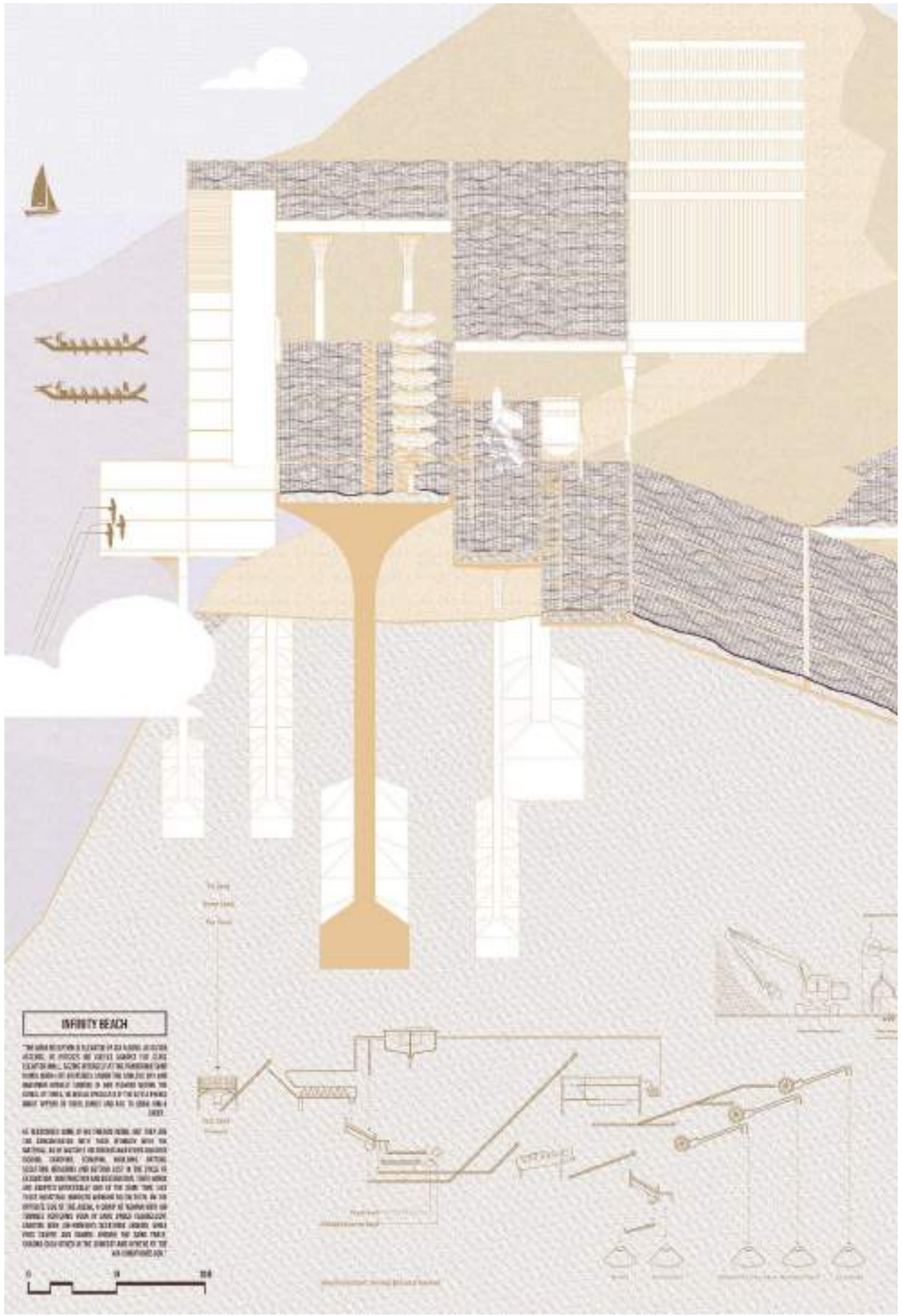
NESTLE WITHIN THE TAMPINES HEARTLANDS, *SUPER BEACH* BRINGS YOU THE COMBINATION OF THE BEST BEACHES AROUND THE WORLD RIGHT AT YOUR DOORSTEP – WITHOUT TRAVELLING TO THE ENDS OF SINGAPORE. IT IS LIKE NO OTHER. GAZING OVER THE GLISTENING BEDOK RESERVOIR, TAMPINES QUARRY, WITH A 360° INFINITY EDGE, YOU WILL FIND ANOTHER SPECTACULAR GETAWAY SPOT IN SINGAPORE. STRETCH OUT TO SUNBATHE ON A LUXURIOUS ELEVATED DECK OR SCRUNCH YOUR TOES IN THE SOFTNESS OF THE FINE-GRAINED, SPARKLING SAND SPECIALLY SANITISED FOR YOUR HYGIENE. ESCAPE INTO A TRIBE OF ACTIVITIES ON THIS PERMANENT URBAN BEACH FOR YOU AND YOUR FAMILY AS BLAZES OF PARASOLS, DUNES OF AIR-CONDITIONED SAND-PITS, THE LARGEST SAND SLIDE ON THE EQUATOR, CRÈCHES, AND BEACH VOLLEYBALL COURTS LINE UP THE PARADISE.

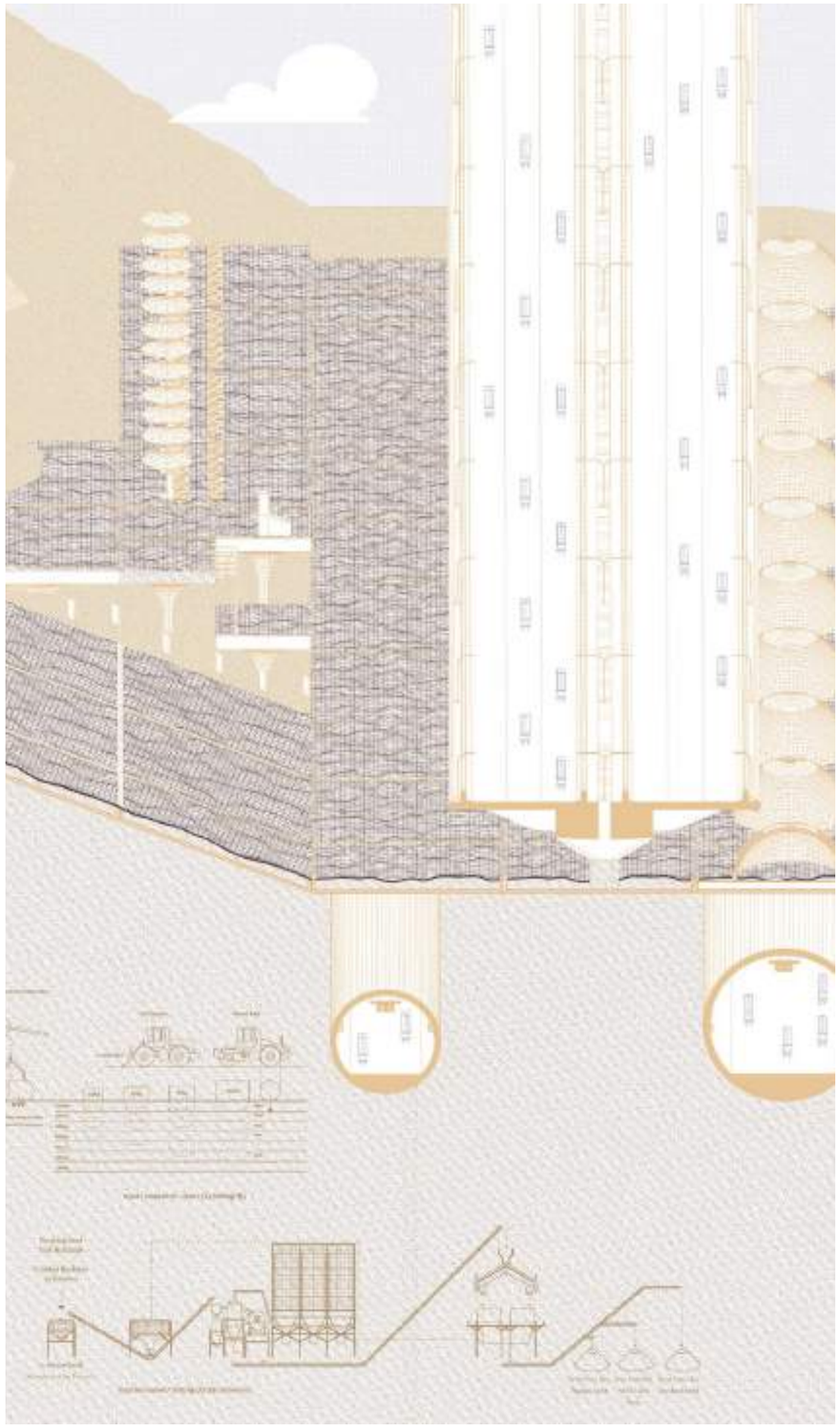

THE VILLA

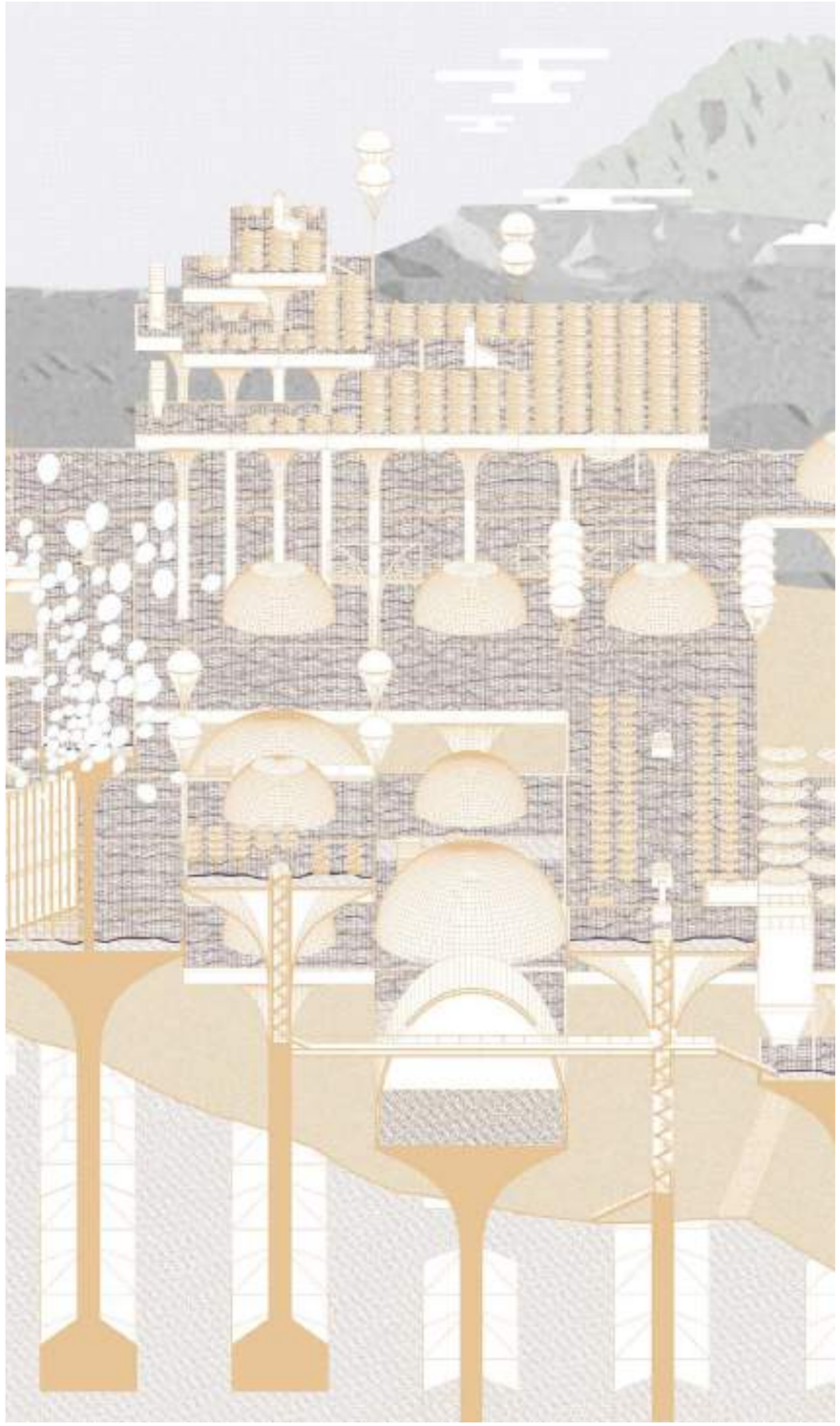
3B. [Opposite]
Infinity Beach. Computer generated drawing. Print. 1:250 on 594 x 1782mm.

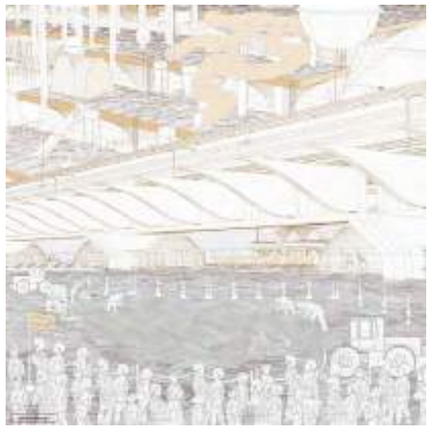
3A. [Previous Spreads]
The Vast. Computer generated drawing. Print. 1:250 on 841 x 1189mm.

A vast expansive beach is juxtaposed against the urban housing estate in Tampines. Stretching beneath Bartley Viaduct and cantilevering over Tampines Quarry and Bedok Reservoir, the beach provides different vantage points for a spectacular view of the sand in Tampines Stockpile across its various elevations. The constructed beach is one that can thus exist without a shoreline as sanitised sand is poured over modular containers installed on site. Expounding on the artificiality of sand, the beach is an 'out-of-this-world' experience where the two infinity edges on the two water bodies give it no seeming end as a surreal image that overpowers the visceral. The beach operates as a leisure phalanstère close to public access in a highly organised manner – from sanitised indoor sandpits to open-air sand slides - whereby sanitised sand is frolicked with and used in seemingly mundane ways in their clear delineated zones.







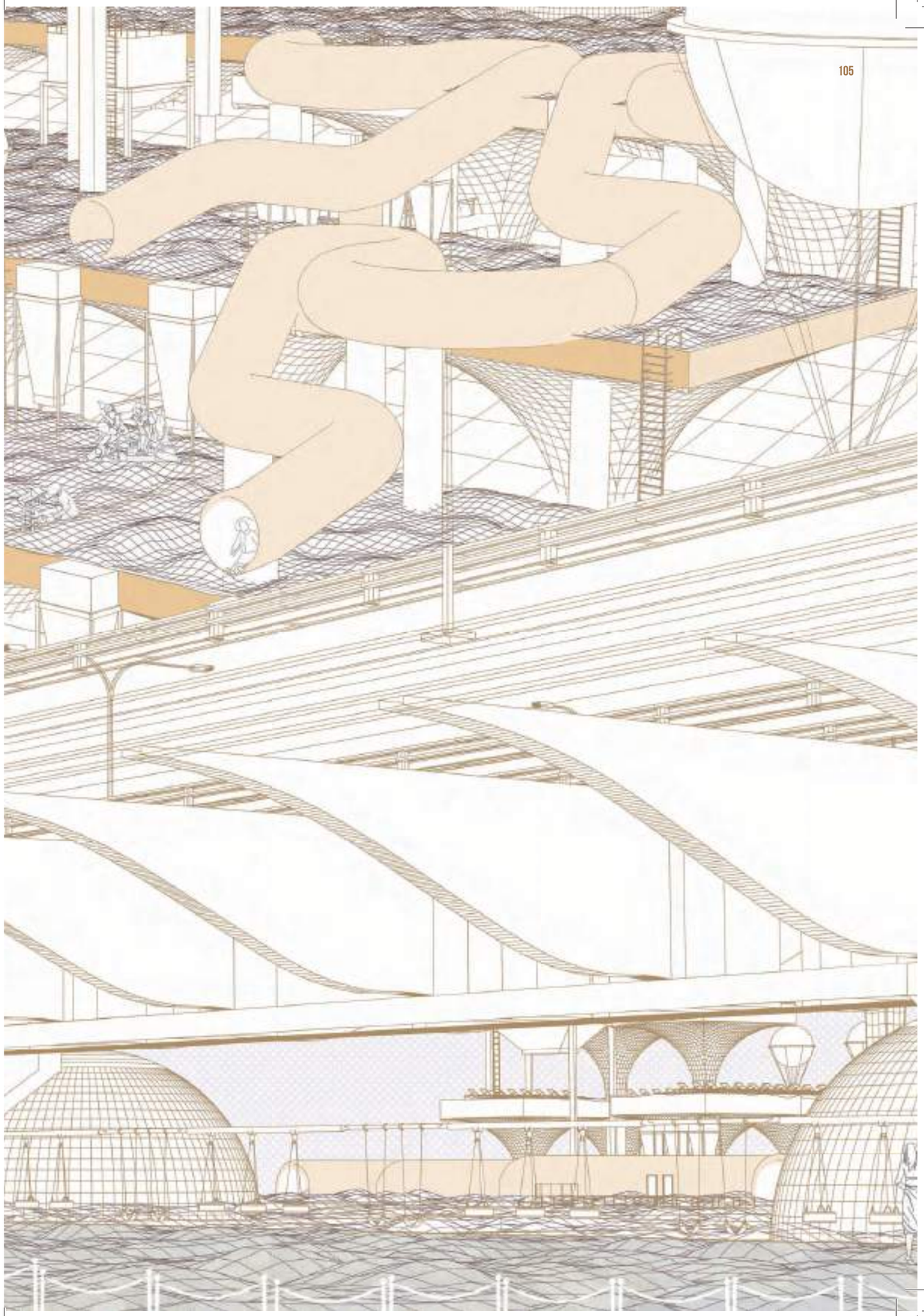


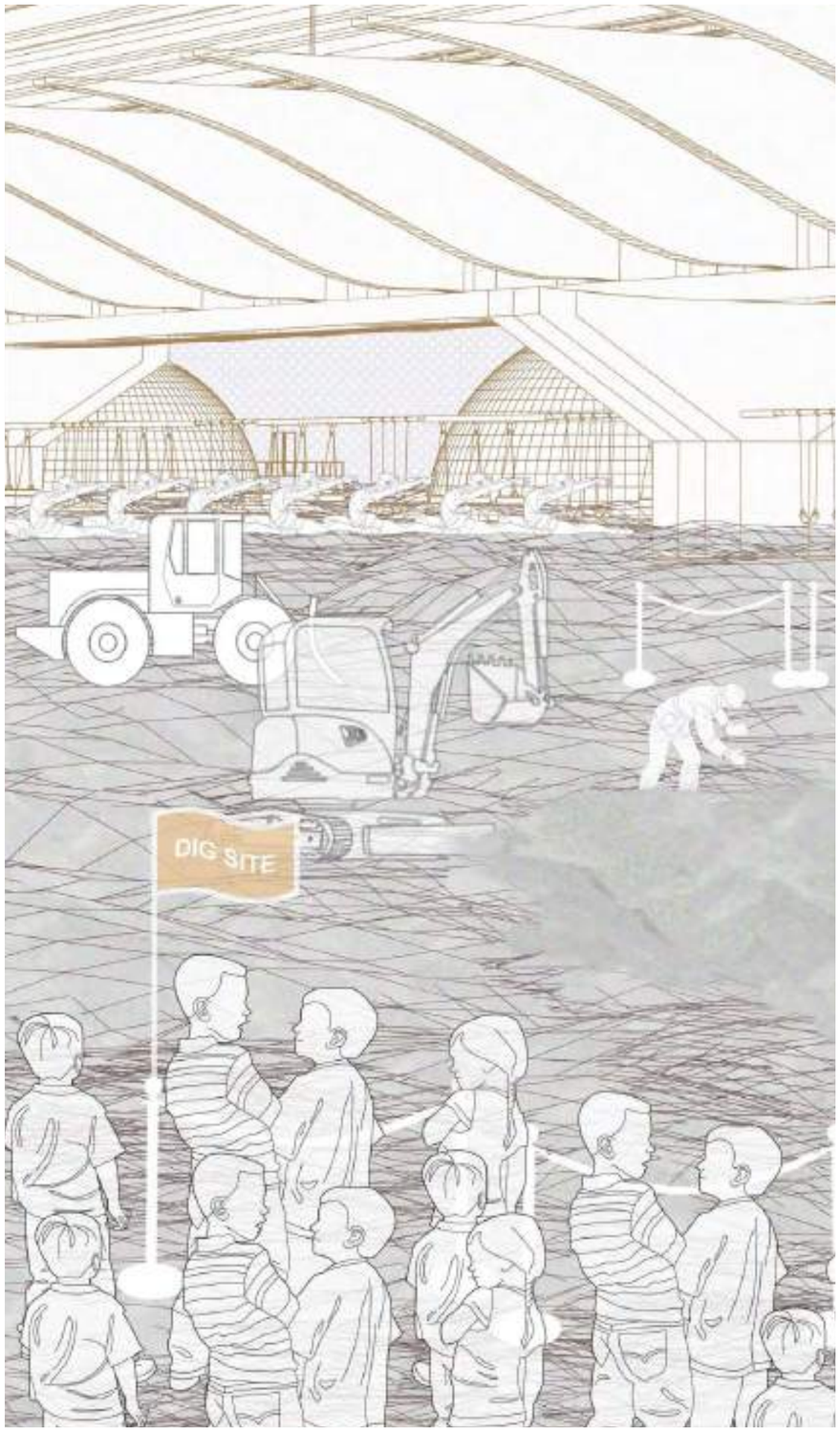
Top - Bottom

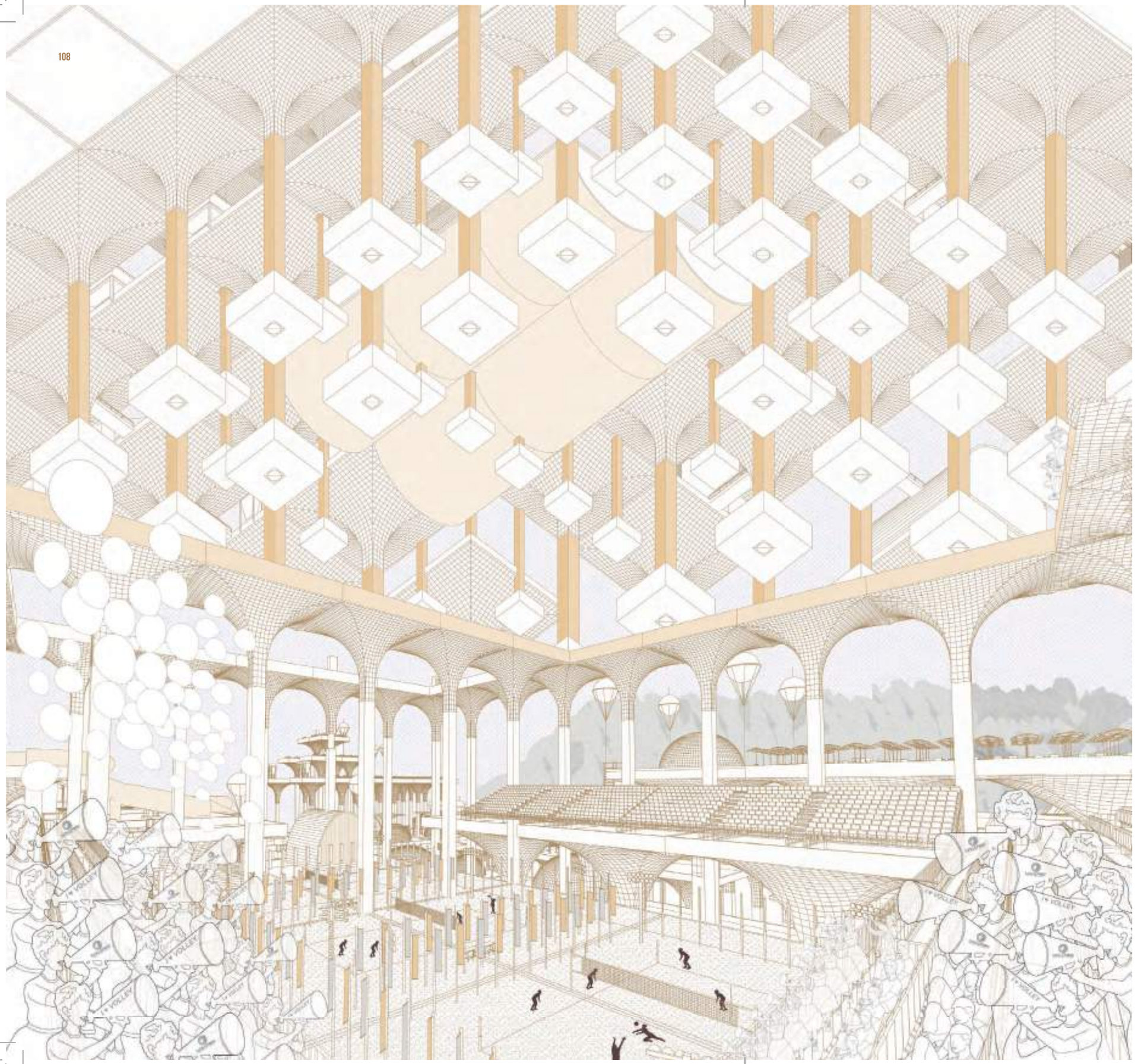
3C_1. Sanitised Sandcastle. Computer generated drawing. Print. 594 x 594mm.

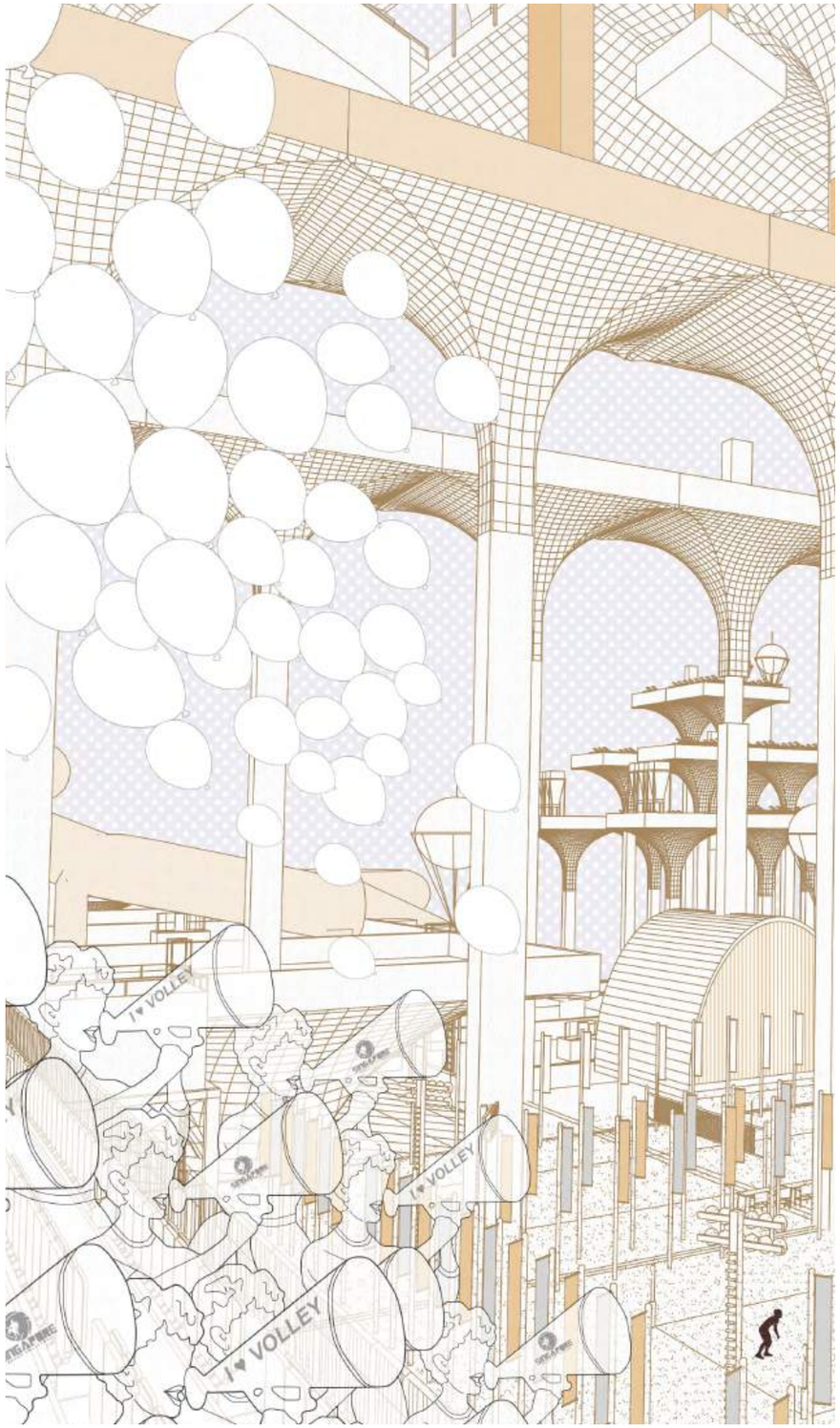
3C_2. Best Views. Computer generated drawing. Print. 594 x 594mm.

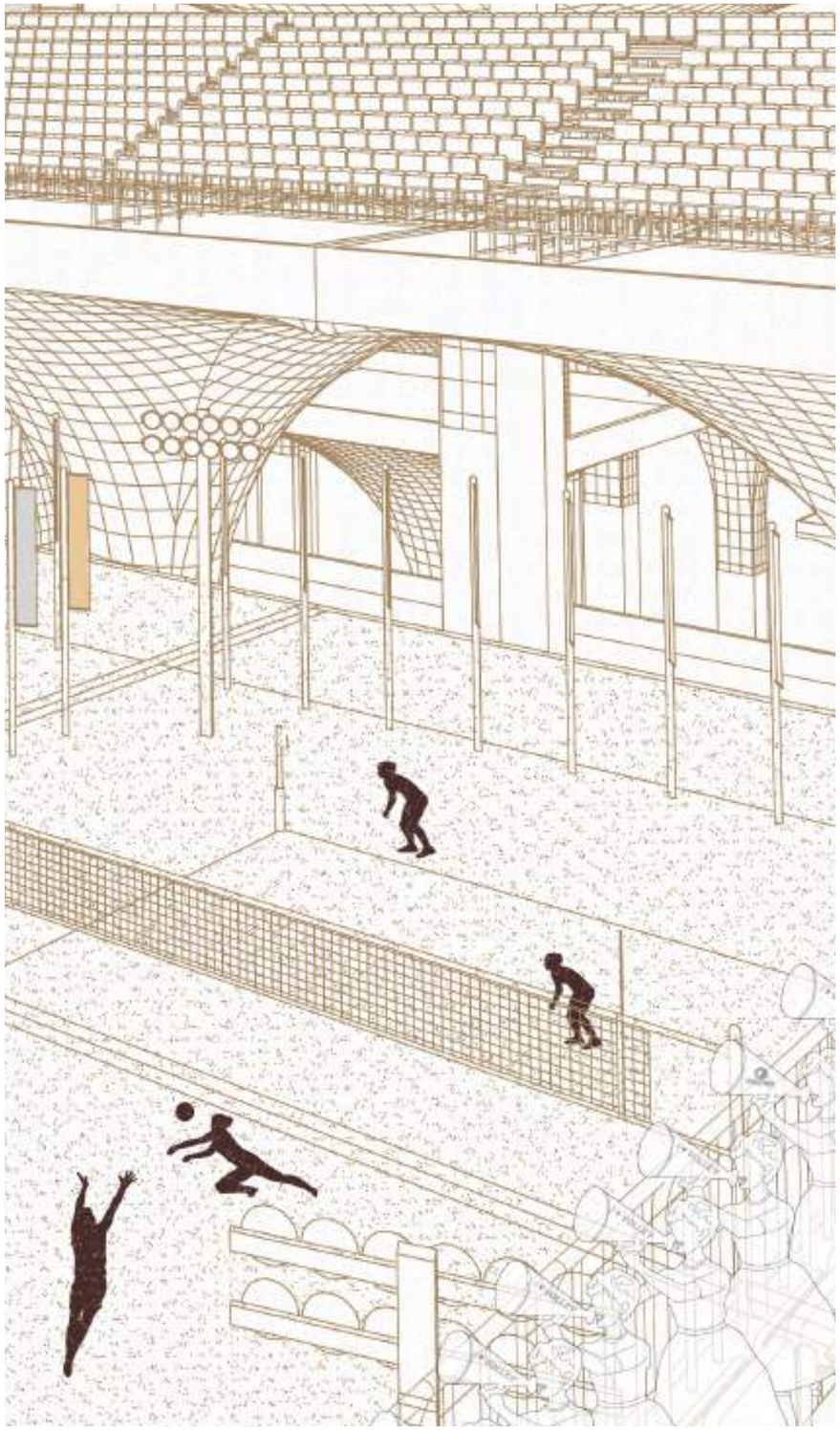
3C_3. New Boundaries. Computer generated drawing. Print. 594 x 594mm.

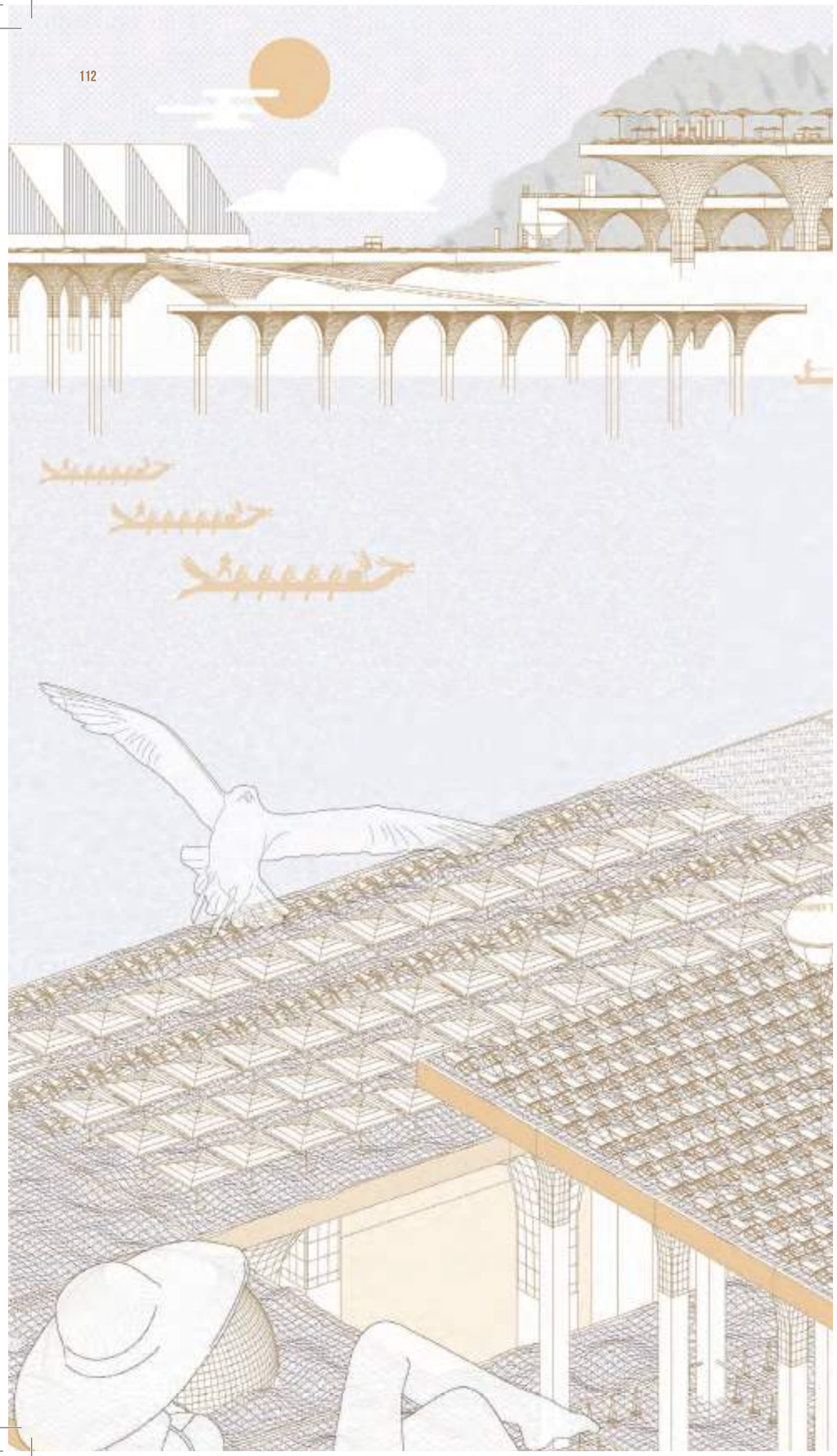


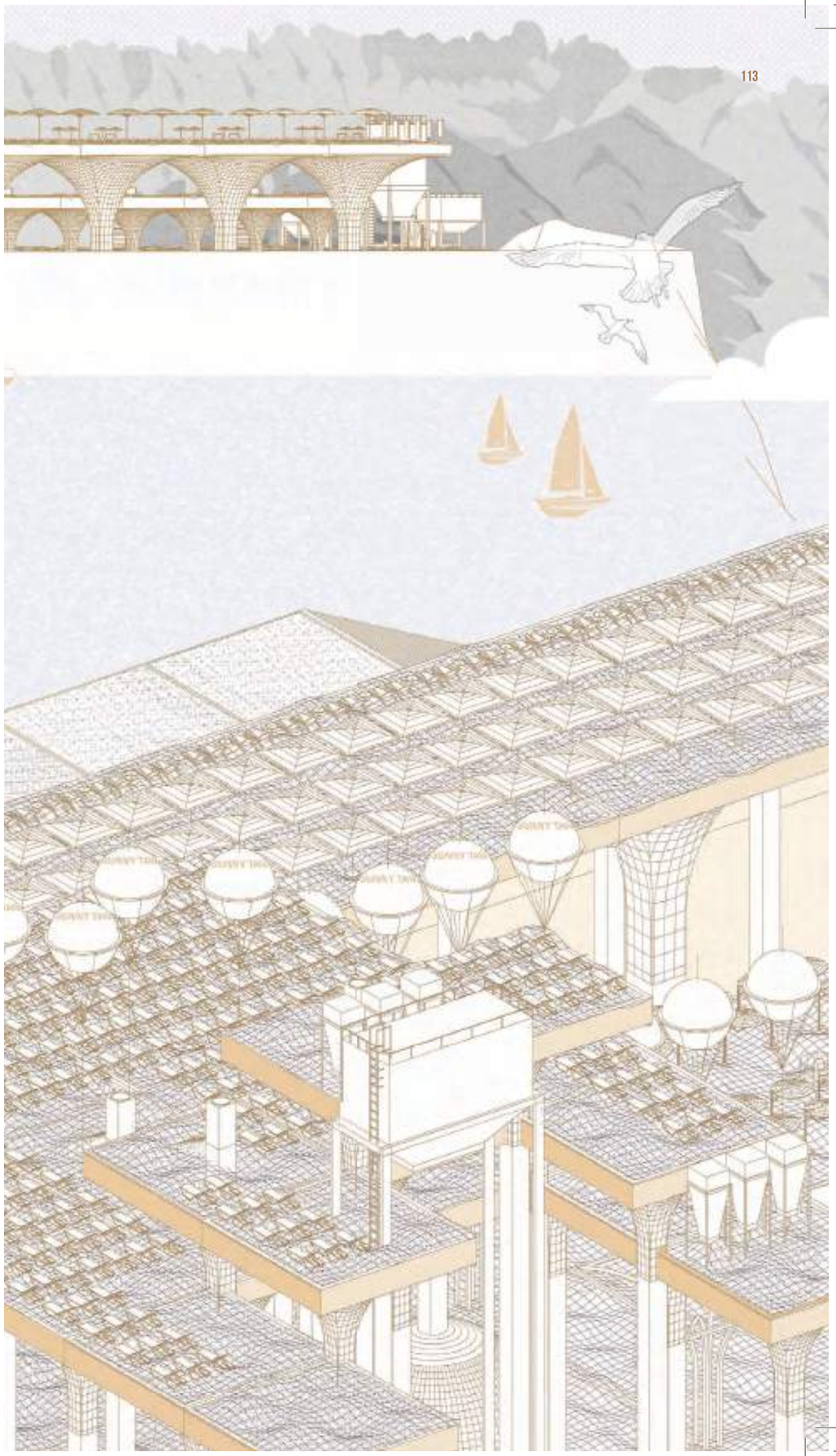

DIG SITE

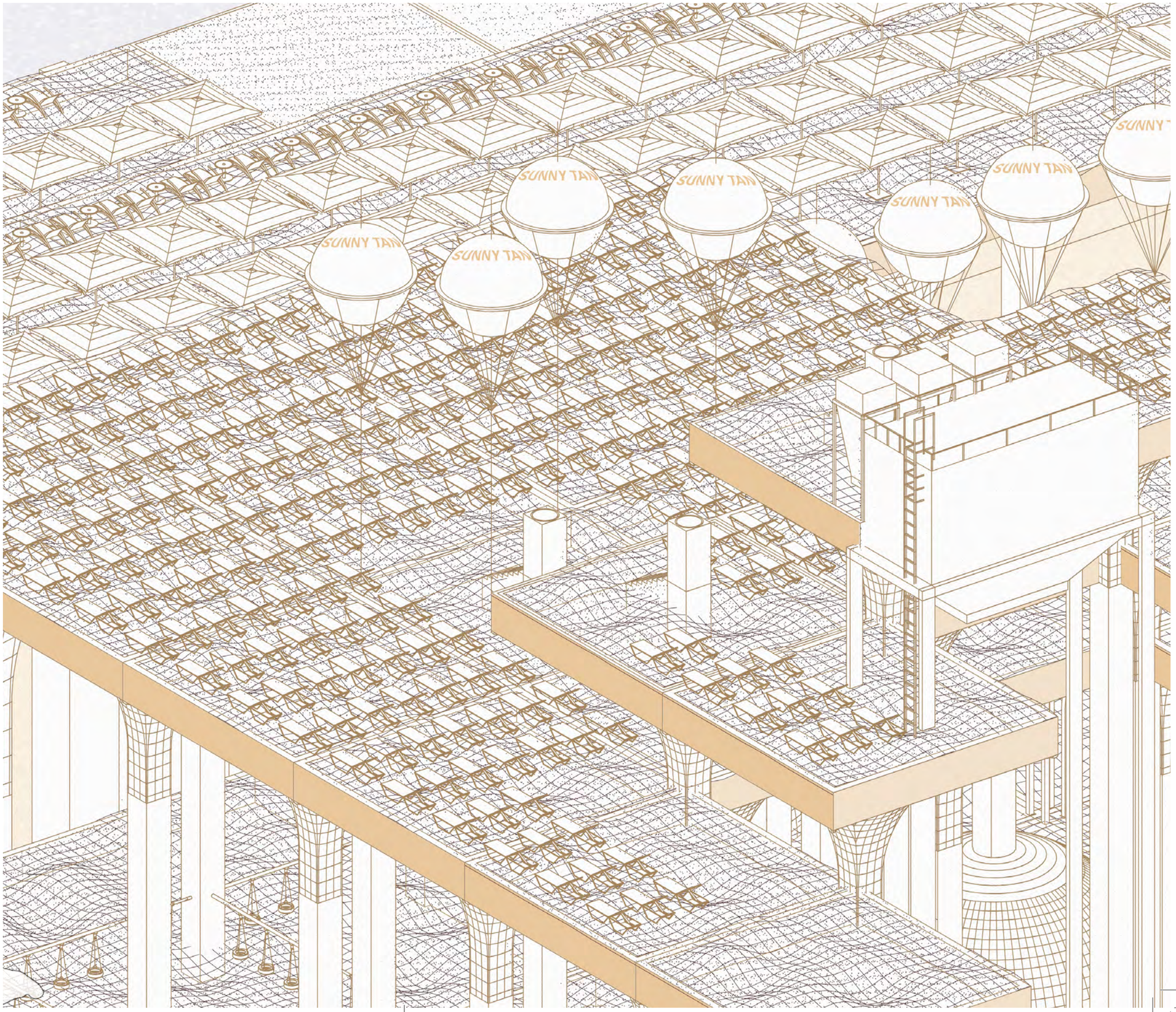



I ♥ VOLLEY
I ♥ VOLLEY
I ♥ VOLLEY









New Boundaries - Expansive sun tanning decks and beach lounges are available for vacation seekers - enjoying the view from the infinity sand-pool

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DT003. Overlook. Bedok Reservoir overlooking Tampines Stockpile. Tampines on second visit, 2018.

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PLATES
Submitted Drawings

[B-Scrolls]

1B. Precarious Dunes. Computer generated drawing. Print. 1:250 on 594 x 1782mm.

2B. Islands of Lairs. Computer generated drawing. Print. 1:250 on 594 x 1782mm.

3B. Infinity Beach. Computer generated drawing. Print. 1:250 on 594 x 1782mm.

[C-Scrolls]

1C_1. Month 3 - Marksman. Computer generated drawing. Print. 594 x 594mm.

1C_2. Month 6 - Paintball. Computer generated drawing. Print. 594 x 594mm.

1C_3. Month 12 - Maintenance. Computer generated drawing. Print. 594 x 594mm.

2C_1. 6pm - Embarkment. Computer generated drawing. Print. 594 x 594mm.

2C_2. 6am - Hangover. Computer generated drawing. Print. 594 x 594mm.

2C_3. 12am - Hedonists. Computer generated drawing. Print. 594 x 594mm.

3C_1. Sanitised Sandcastle. Computer generated drawing. Print. 594 x 594mm.

3C_2. Best Views. Computer generated drawing. Print. 594 x 594mm.

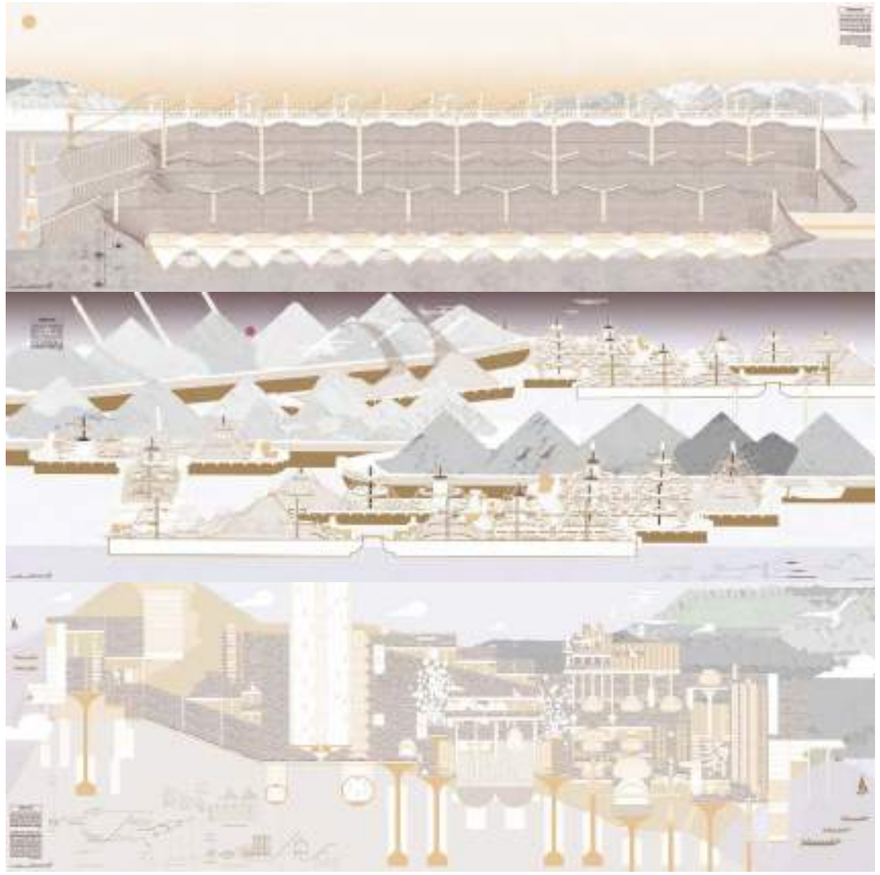
3C_3. New Boundaries. Computer generated drawing. Print. 594 x 594mm.

[A-Panels]

1A. The Leaky. Computer generated drawing. Print. 1:250 on 841 x 1189mm.

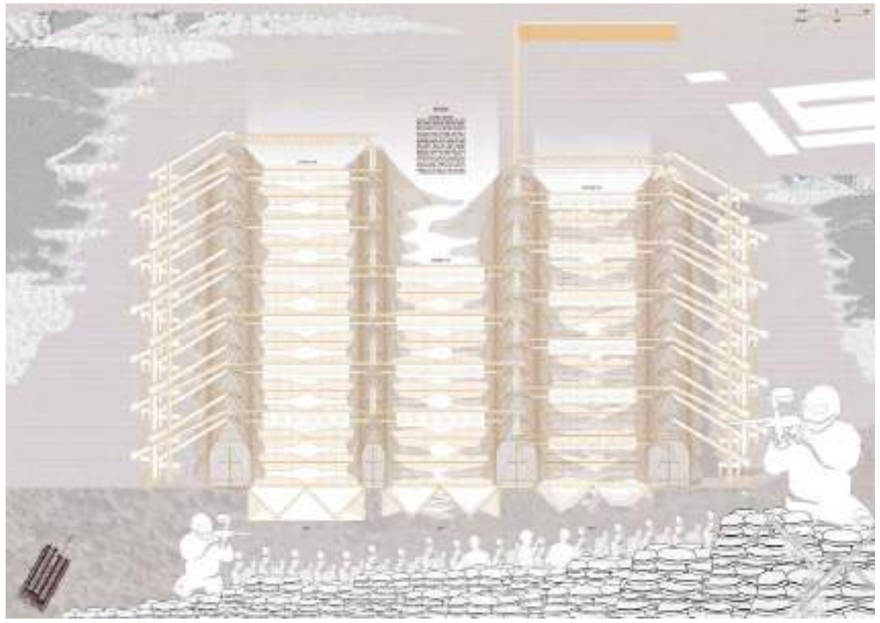
2A. The Flamboyant. Computer generated drawing. Print. 1:250 on 841 x 1189mm.

3A. The Vast. Computer generated drawing. Print. 1:250 on 841 x 1189mm.



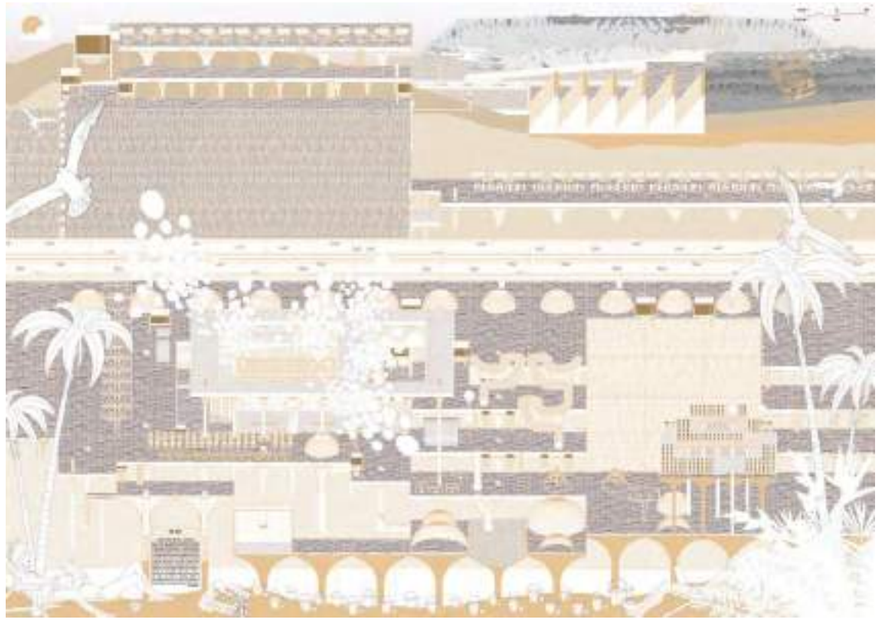
B-Scrolls. Order: T - B

C-Scrolls. Order: L - R, T - B.



1A. The Leaky. Computer generated drawing. Print. 841 x 1189mm.

2A. The Flamboyant. Computer generated drawing. Print. 841 x 1189mm.



3A. The Vast. Computer generated drawing. Print. 841 x 1189mm.

APPENDIX
Situating Spectacle

[Singapore's sand stockpile in 15 photographs, *Timber frame, 297 x 297mm*]

FS01. Tea-Break. Workers taking a break from manicuring sand piles. Seletar Link. 2017.

FS02. Houses Built On Sand. Stockpile sitting inertly against Punggol Waterfront Estate on a drizzling day. 2017.

FS03. Manicure. Workers plucking weed out of sand stockpile. Seletar Link. 2017.

FS04. Teletubbies Might Appear. Rows of sand piles and exposed drainage pipes. Seletar Link. 2017.

FS05. Maintenance. Military vehicle garage and Seletar Stockpile. 2017.

FP01. Sand Up. Loaded tipper tuck exiting Pulau Punggol Aggregate Terminal , set aganist Punggol Waterfront Estate. 2017.

FP02. Nature's Revenge. Pulau Punggol Timor. 2017.

FP03. Fresh Arrivals. Behind-the-fence sand processing in Aggregate Terminal. 2017.

FP04. Secret Mountain. Imported sand piled inside Punggol's Aggregate Terminal. 2017.

FP05. Regulated Waters. Standing on Punggol coastline on a drizzling day. 2017.

FT01. Highway View. Driving up Bartley Viaduct. 2018.

FT02. Sand Drive. Tampines stockpile along Bartley Viaduct. 2018.

FT03. Singapore Desert. Massive landscape along Bartley Viaduct. 2018.

FT04. All Natural. Sand dunes seen from Tampines Quarry. 2017.

FT05. I'm Home. HDB Tampines Sand Stockpile Site. 2017.

[Behaviourology]

DB000. Tropical Arid. Standing on Bartley Viaduct. Tampines on second visit, 2018.

DB001. A small pile of big. Sand particles in a sand pile. See figure FP103 Sand classification table in *Materialising Sand: Volume 1* for the constitutions of sand as a matter.

DB002. Sand Behaviours Index. Due to sand's material properties, they behave in a certain way upon external forces acting on it. List is not exhaustive. Drawing reconstructed from Allen, 469-471.

DB003. Angle of Repose. This is the steepest angle of dip relative to the horizontal plane to which sand can be piled without slumping, anything more, slope surface will slide. Sand has a predetermined angle of repose from 34° to 45°. Generally, the rougher the grains the steeper the angle due to their ability to better interlock. Reference: Glover, Thomas J. P*ocket Ref.* 4th ed. Sequoia Publishing, 2010.

DB004. Sand Dune Profile.

DB005. Aeolian Sand Dunes. Geometries shaped naturally by wind velocity and sand supply. Sand particles moves with the wind direction. These typologies are found in different places on the Earth's surfaces according to global wind movements.

DB006. Wind Simulations. Performed under artificial condition, sand as an aggregate pile morphs, shifts position, and oeirntates with wind movement as each grain saltates, suspends and displaces.

DB007. Particle Saltation. Performed under artificial condition. Sand as an aggregate pile morphs and shifts position with wind movement as each grain saltates, suspends and displaces.

DB008. Barchan Typology. Postulated (convex) sand dune alteration with varying wind speed over a period of 12 months. Referenced from Kotenko, Anastasia, and Niki Kakali. 'Aeolian Sand Odyssey'. Landscape Urbanism, Architectural Association, 2014.

DB009. Parabolic Typology. Postulated (concave) sand dune alteration with varying wind speed over a period of 12 months. Referenced from Kotenko, Anastasia, and Niki Kakali. 'Aeolian Sand Odyssey'. Landscape Urbanism, Architectural Association, 2014.

DB010a. Plan of Deposit.

DB010b. Section Profile of Deposit.

DB011a. Obstacles and Artificial Conditions. An abstract object is placed in the middle of a sand pile where conditions are artificially exaggerated and controlled to expedite the morphology process and achieve certain forms on purpose.

DB011b. Expedited Burial. As sediments accumulate overtime, the obstacle will eventually be buried in sand.

DB012a. Obstacle Simulation A. Obstacles with an angle to the wind flow shape the dune movements perpendicular to themselves - turning dunes movement direction.

DB012b. Obstacle Simulation B. Straight wall variation.

DB012c. Obstacle Simulation C. Dunes tend to turn their crest parallel to the obstacles they meet with in their moving direction/ wind direction.

DB012d. Obstacle Simulation D. Obstacles with an angle to the wind flow shape the dune movements perpendicular to themselves - turning dunes movement direction.

All images, drawings and photographs are produced by author in 2018, unless otherwise stated.

DB013. Artificial Sand Pile. Geometries formed as a result from pragmatic storage purpose - fresh off conveyor mills and sand barges. These typologies are found in sand stockpiles.

DB014. Piling Sand. Drawing based on observations outside a cement plant in Punggol. Extension to figure AA06 Formation Method: Artificial Sources, and AA07 Frac Sand Plant Process of *Materialising Sand, Volume 1*.

DB015. Sand Terrace. Tampines on second visit.

DB016. White Mounds. Tampines on second visit.

DB017b. Compacting Sand - Impact. Stress is applied by dropping a large mass onto the surface of the soil. Drawing not to scale.

DB017d. Compacting Sand - Rolling. A heavy cylinder is rolled over the surface of the soil. Often fitted with vibratory devices. Commonly used on sports pitches. Reconstructed from Danneberger, Karl. 'The Science of Soil Compaction'. *SportsField Management*, 2013. Drawing not to scale.

DB018a. Mixture A. 1 : 1 [Sand : Water]

DB018b. Mixture B. Kinetic Sand with Scenic Spray

DB018c. Mixture C. 1 : $^{1}/_{8}$ [Sand : Water]

DB018d. Mixture D. 1: $^{1}/_{8}$ [Sand : Seawater]

DB018e. Mixture E. 1 : ½ : ¾ [Sand : Cornstarch : Water]

DB018f. Mixture F. 2 : 1 : 1 [Sand : White Glue : Cornstarch]

DB018f. Cooking mixture E over heat.

[The Dunes]

DS001. Seletar Intervention. Scale [1:5000 on an A4]

DS002. Dunes Pattern. Scale [1:500 on an A4]

[The Archipelago]

DP001. Punggol Intervention. Scale [1:5000 on an A4]

DP002. Barge Pattern. Scale [1:500 on an A4]

[The Beach]

DT001. Tampines Intervention. Scale [1:5000 on an A4]

DT002. Beach Pattern. Scale [1:500 on an A4]

DT003. Overlook. Bedok Reservoir overlooking Tampines Stockpile. Tampines on second visit, 2018.

ACKNOWLEDGMENTS

This second volume is both a proposition and reflection of a question that is urgent: what can architecture do in light of a national resource crisis? Or rather, how can it contribute? Architecture is a tough discipline of making. It involves negotiating through poetry, abstraction, the immaterial and tangible, practicality and technical limits. The study of sand from its politics to materiality had led to my intention to question our relationships and vulnerabilities with sand through architecture. The use of design as a method to pursue this intention was both challenging and tedious. I am grateful to the following people who made the past eight months fulfilling:

My parents, for your undying love and support – from helping me with my sand models to accommodating my request to transform most of the house into a sandy workspace. I am indebted.

YC, for keeping my sanity as we blaze through two separate projects in parallel with thesis. Your systematic organisation kept me in check as we multitask our various other roles; while I continue to flood your whatsapp when shit happens. Shan, Jong, Chiew, Isabel, Kyra, Yanjie, and Yuqi for sticking around during the lowest times and giving your help and encouragements all these while.

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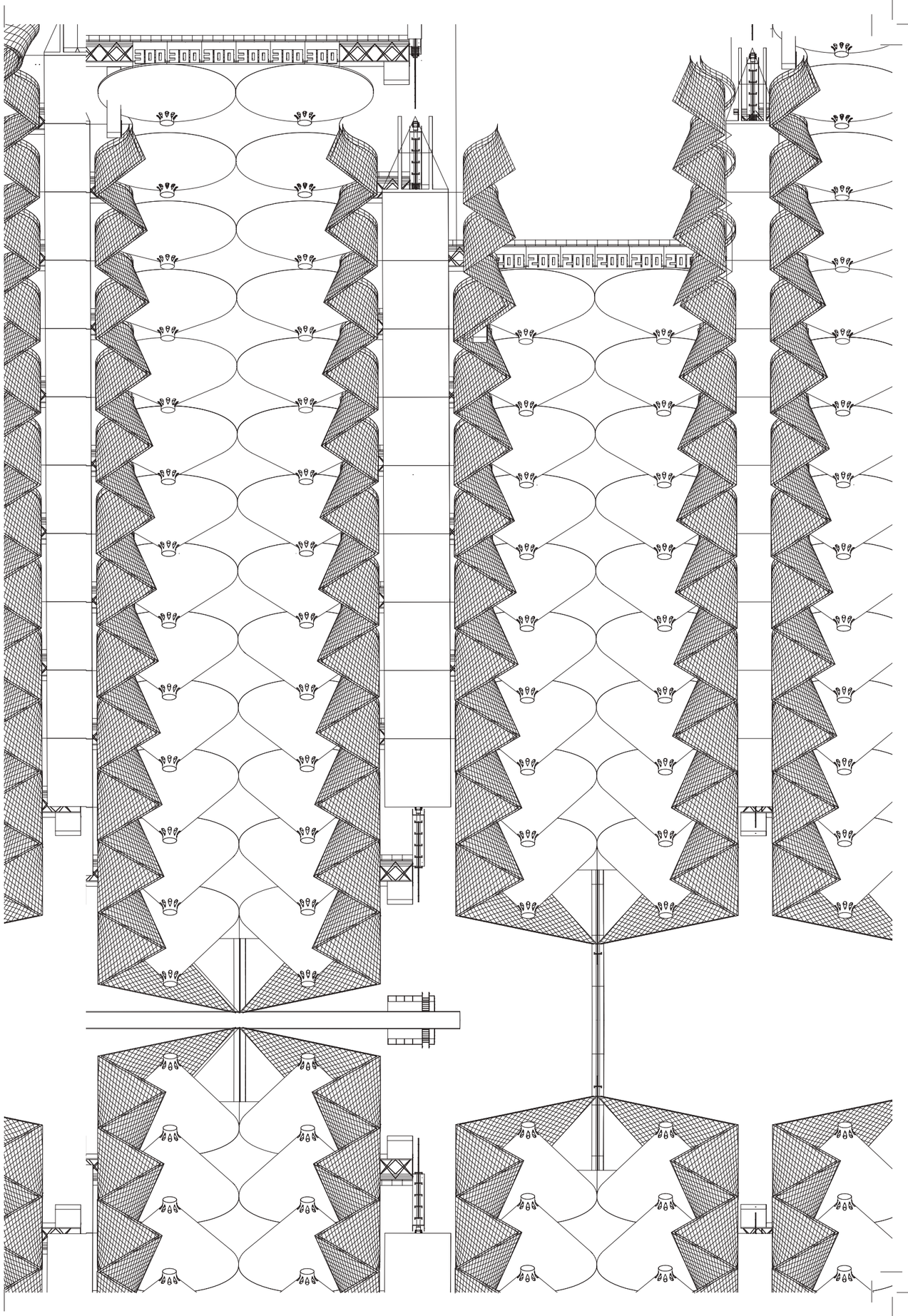
Thank you for the five years.



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