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Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through

Biotope Mapping Abstract 1 This study assesses the ecological structure of the 979.12-
hectare Bonifacio Global City sub-watershed in Metro Manila and develops 2 an Ecological
Cooling Network Plan to address rising land surface temperatures and fragmented
vegetation in a highly urbanized 3 environment. Biotope mapping identified twenty-one (21)
biotopes and fifty-one (51) units derived from land cover, landform, and 4 soildata. These
were evaluated using the Period of Development (D), Area (A), Rarity (R), and Habitat (H)
criteria to determine their 5 ecological and cooling value. Built-up biotopes dominated the
landscape, occupying more than ninety-four percent (94%) of the total 6 area, while green
biotopes such as Level Green Spaces, Undulating Green Spaces, and Rangelands
accounted for only small, scattered 7 patches. These remaining vegetated areas were
classified as cooling cores due to their relatively high cooling value, while the Pasig 8 River
corridor and its vegetated segments functioned as cooling corridors linking isolated
patches. Heat-intensive built-up zones with 9 limited vegetation were designated as priority
areas for cooling interventions. Management strategies included Creative Management 10
for areas requiring the introduction of vegetation, Improvement Management for biotopes
with moderate cooling potential, and 11 Conservation Management for the few high-value
green spaces. The Ecological Cooling Network Plan proposes the expansion of 12 cooling
nodes, enhancement of vegetated corridors, and strengthening of connectivity across the
sub-watershed. The study highlights 13 the importance of biotope mapping and remote
sensing in understanding thermal patterns and guiding nature-based planning to 14
improve urban resilience in rapidly developing districts. 15 16 Keywords: urban heat,
biotope mapping, ecological planning, cooling network, geographic information systems,
Metro 17 Manila 18 19 20 21 22 _____ 23 Marielle Eimee G. Aquino is a

student of the Bachelor of Landscape Architecture program at the University of the

Philippines Diliman. Her 24 academic interests focus on ecological planning, climate-responsive design, and GIS-based spatial analysis, with particular emphasis on 25 nature-based approaches for addressing dense urban metropolitan environments. 26 I.

Introduction 27 28 1.1 Background 29 Urbanization continues to reshape the landscape of Metro Manila and has resulted in significant alterations to local 30 microclimates. As built-up areas expand, natural land covers are replaced with impervious materials such as concrete, 31 asphalt, and glass (Aghazadeh et al., 2025). These surfaces absorb and store heat during the day and release it slowly at 32 night, which intensifies the Surface Urban Heat Island (SUHI) effect. Recent research shows that highly urbanized districts 33 experience higher land surface temperatures because of reduced vegetation, increased building density, and concentrated 34 human activities (Xie et al., 2024). 35 36 Dense commercial districts such as Bonifacio Global City (BGC) and the Ortigas to Makati are expected to exhibit elevated 37 SUHI intensity. These areas contain extensive impervious surfaces and high-rise developments that limit airflow, reduce 38 shading, and minimize opportunities for natural cooling. Similar patterns have been documented in other Asian 39 megacities where land cover composition, urban morphology, and local climate zones strongly influence surface 40 temperature variations (Moazzam et al., 2024). 41 42 Understanding heat distribution in rapidly developing metropolitan regions benefits from a watershed-scale perspective. 43 2 A watershed is an integrated environmental system that connects landform, hydrology, soil conditions, and ecological 44 structure. This perspective allows researchers to analyze how biophysical features interact with urban development to 45 influence microclimates. Recent studies emphasize that examining SUHI within a landscape and watershed framework 46

captures spatial heterogeneity more effectively and helps identify potential cooling corridors along rivers, open spaces, 47 and green structures (Yang, 2024). 48 49 In Metro Manila, the Pasig 2 River and its tributaries influence local temperature patterns by providing blue and green 50 infrastructure corridors. However, the cooling potential of these waterways depends on the continuity of vegetated 51 riverbanks, the permeability of surrounding land covers, and the level of ecological connectivity within the urban 52 landscape. A watershed perspective therefore provides a more holistic understanding of heat distribution in highly 53 developed areas such as the Bonifacio Global City(BGC) and Ortigas to the Makati region. 54 55

1.2 Ecological and Urban Challenges 56

The study area experiences rising land surface temperatures due to rapid urban expansion and the spread of impervious 57 surfaces. Studies in Metro Manila and other tropical cities consistently show that dense built-up areas record higher 58 surface temperatures because of reduced natural cover and increased heat retention (Magnaye&Kusaka, 2024). 59 60 In addition, the loss of vegetation further intensifies heat. Reduced tree cover limits shading and evapotranspiration, both 61 of which are essential for cooling, and research confirms that declining green cover directly increases urban heat exposure. 62 Existing cooling spaces within the sub-watershed are highly fragmented. Small parks and isolated patches of vegetation 63 lack connectivity, which weakens their collective cooling performance across the landscape. As a result, urban heat tends 64 to accumulate in major commercial districts such as Bonifacio Global City (BGC) and surrounding mixed-use areas, which 65 consistently appear as thermal hotspots in local heat island analyses (Purio et al., 2022). 66 67 Finally, the condition of the Pasig River corridor limits its potential as a cooling feature. Although rivers can moderate 68 urban temperatures, studies in Metro Manila show that hardened riverbanks and insufficient riparian vegetation reduce 69 the effectiveness of blue-green networks in providing cooling benefits (Ibañez, 2024). 70 71

1.3 Biotope Mapping 72

Understanding urban heat within a rapidly developing watershed requires an integrated spatial approach that considers 73 the interaction of land cover, landform, soil type, and hydrology. Remote sensing and

geographic information systems 74 (GIS) provide the analytical foundation for assessing these conditions at a landscape scale, allowing a holistic 75 understanding of how built-up density and natural features influence thermal patterns in the study area. 76 77 Central to this study is the use of biotope mapping, which classifies the landscape into ecologically meaningful units. This 78 method allows detailed examination of the condition and ecological role of different spaces while enabling a structured 79 interpretation of how each biotope contributes to thermal regulation. 80 81 Recent applications of biotope mapping demonstrate its effectiveness in analyzing ecological structure in both densely 82 urbanized and transitional landscapes, identifying areas with potential cooling benefits and areas vulnerable to heat 83 accumulation. Used in Philippine planning studies, such as urban greening assessments in Pasig City and ecological 84 structure mapping in the University Belt, showed that spatial analysis and biotope-based classification can guide local 85 climate resilience strategies (Ibañez, 2024; Sibayan, 2025). International studies also support this approach, including UHI 86 network mapping in Nanjing and green space cooling analyses in Guangzhou (Wang & Hu, 2025; Zhang et al., 2025), both 87 of which emphasize how spatial configuration and ecological connectivity influence land surface temperature. Together, 88 these demonstrate that integrating biotope mapping with land surface temperature and spatial analysis can effectively 89 inform urban heat mitigation planning. 90 91 1.4 Research Goals 92 This study aims to evaluate the existing thermal and ecological conditions within the Bonifacio Global City (BGC) sub93 watershed and surrounding barangays by applying biotope mapping and ecological management and networking. 94 Through this approach, the study seeks to respond to increasing land surface temperatures, fragmented green spaces, and 95 degraded river corridors in a highly urbanized district. 96 97 Specifically, the goals of this study are (1) to identify the existing biotopes and ecological structures in the study area, (2) 98 to determine the ecological value of each biotope using modified D–A–R–H criteria, and (3) to develop an ecological plan 99 that enhances cooling networks, strengthens connectivity, and supports climate-adaptive urban development. This study 100 hypothesizes that an integrated

ecological planning approach can improve thermal regulation while supporting urban 101
resilience and climate adaptation in Metro Manila. 102 103

Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through
Biotope Mapping Aquino 3 MUHON: A Journal of Architecture, Landscape Architecture and
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Methodology 104 105 2.1 Delineation of Site Boundary 106 The extent of Bonifacio Global
City (BGC) and its surrounding barangays was first used to establish the minimum area of
107 interest for the study. From this baseline, the sub-watershed was delineated by
identifying local high points in the terrain 108 and mapping natural runoff flow toward the
Pasig River, which serves as the main drainage outlet for the area. 109 110 This process
outlined the surfaces that drain into the river, forming a sub-watershed within the larger
Pasig River Basin. 111 The final delineation covers approximately 979.12 hectares and
consists mainly of dense built-up zones and limited green 112 areas that influence the
urban heat conditions of the site. 113 114 115 116 Figure 1. Watershed Delineation of
the Study Site. 117 118 2.2 Biotope Mapping Approach 119 Biotope maps can be
generated from the overlay of three (3) land classification maps: soil map, landform map,
and land 120 cover map which indicate hydro-geological features, soil and vegetation
characteristics, urban development, and 121 remaining open spaces. In this study, soil
classifications were obtained from the Philippine Geoportal (NAMRIA), 122 landform data
were derived from the SRTM Digital Elevation Model accessed through USGS Earth
Explorer, while land 123 cover classifications and urban green space features were
obtained from Philippine Geoportal and OpenStreetMap 124 datasets. 125 126 To
incorporate thermal conditions, a Land Surface Temperature (LST) map was generated
using the Thermal Infrared 127 Bands of Landsat 8/9 imagery, processed to obtain annual
mean LST values. The LST layer was then integrated with soil, 128 landform, and land
cover maps in a GIS environment to delineate distinct urban heat biotopes within the Pasig

River subwatershed. 130 131 Table 1. Summary of data sources for each land classification map type. 132 Map Type Acquired Data Data Source Soil Type Map Soil Classifications Philippine Geoportal (NAMRIA) Landform Map Topography Data USGS Earth Explorer– SRTM Landcover Map Land cover classifications; Land use green spaces Philippine Geoportal (NAMRIA); OpenStreetMap (OSM) Land Surface Temperature Map Annual mean LST values Landsat 8/9 Thermal Infrared Data (USGS) 133

Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through Biotope Mapping Aquino 4 MUHON: A Journal of **1 Architecture, Landscape Architecture and the Designed Environment University of the Philippines College of Architecture** Issue No. _ 2.3

Biotope Assessment 134 The ecological value of each biotope identified in the biotope map was assessed using four (4) criteria: Period of 135 Development, Area, Rarity, and Habitat (Jarvis & Young, 2005), with parameters modified to suit the urban conditions of 136 the study area. A rating value ranging from one (1) to five (5) was assigned for each criterion, and the total score was used 137 as the basis for determining the cooling value and priority management of each biotope. 138 139 The Period of Development (D) refers to the time required for a biotope to establish structural complexity. Biotopes with 140 longer development time (such as mature tree canopy or established vegetation) were given higher scores due to their 141 greater cooling capacity and structural stability. Area (A) indicates the total spatial extent of the biotope, where larger 142 biotopes are valued higher because they function as potential cooling cores and can influence wider thermal conditions. 143 Rarity (R) represents how unique or scarce a biotope is within the sub-watershed; biotopes that are limited in number or 144 isolated from similar types were given higher ratings due to their irreplaceable cooling role in dense urban settings. 145 Lastly, Habitat (H) refers to vegetation structure and functional capacity. Biotopes with complex vegetation that provide 146 shade, evapotranspiration, and thermal regulation were rated higher than biotopes with simple or low-vegetation 147 structures (such as built-

up areas). The resulting Value Assessment totals allowed the identification of high, medium, and 148 low value biotopes, which informed the proposed ecological cooling strategies and network planning within the study 149 area. 150 151 Table 2. Biotope assessment criteria. 152 Criterion Description Rating Period of Development (D) Duration the community will take to establish itself elsewhere. D1= 0-10 years D2= 10-20 years D3= 20-30 years D4= 30-50 years D5= >50 years Area (A) The larger the area the greater potential of cooling cores for the thermal conditions. A1= 0-1 ha A2= 1-10 ha A3= 10-50 ha A4=50-200 ha A5=200+ ha Rarity (R) Uniqueness of the said biotope. R1= Many similar biotopes occurring R2= 4-5 similar biotopes within 500 -1000 m R3= 3-2 similar biotopes within 2 km R4= One equivalent biotope R5= No equivalent biotopes Habitat (H) Quantity of vegetation structure found. H1= No kind of Vegetation Exist H2=Almost a uniform vegetation structure H3= 2 Different vegetation structure H4= 3 Different vegetation structures H5= Several vegetation structures 153 2.4 Ecological Planning 154 The existing ecological structure within the chosen sub-watershed is identified from the assessment of each biotope and 155 the major biotope categories. Biotopes with the highest value were designated as cores, representing areas with strong 156

Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through Biotope Mapping Aquino 5 ¹ MUHON: A Journal of Architecture, Landscape Architecture and the Designed Environment University of the Philippines College of Architecture Issue No. _

vegetative structure and higher thermal-regulating potential. Existing riverbanks along the Pasig River, linear elements, 157 such as streets and pathways, were identified as corridors, which can connect cooling spaces across the urban fabric and 158 support ventilation flows within the densely built areas of the study site. 159 160 After identifying the existing cores and corridors, an ecological plan was developed to enhance cooling capacity and 161 improve network connectivity. Management strategies were assigned based on the value assessment scores of each 162 biotope using four levels: Creative

(0–5), Improvement (6–10), Conservation (11–15), and Preservation (15–20). These 163 strategies guide appropriate planning actions from creating new cooling spaces in thermally vulnerable areas to 164 improving vegetation in medium-value biotopes, to conserving and preserving high-value cooling spaces. Thereby 165 strengthening the ecological cooling network within Bonifacio Global City and surrounding barangays.

166 167 Table 3. Biotope Management Strategies and Corresponding Score Range. 168

Management Strategies	Description	Range of Biotope Assessment
Creative Establishment of new cooling spaces and green structures in areas with minimal vegetation and high surface temperature	0-5 Improvement	Enhancement of existing biotopes with moderate cooling value through vegetation addition, shading elements, and landscape interventions that increase cooling performance.
6-10 Conservation	Protection and enhancement of high-value cooling spaces that provide significant shading, evapotranspiration, and connectivity, allowing only limited intervention.	11-15 Preservation
15-20	Strict protection of the most critical cooling cores with minimal human intervention.	

169 2.5 Scope and Limitations 170 This study was designed to evaluate urban heat conditions and ecological structure using a remote-sensing–based biotope 171 mapping approach. Field validation and on-site ecological surveys were outside the scope of the research, and the analysis 172 relied entirely on satellite-derived and secondary spatial datasets. While this method enables consistent and efficient 173 assessment of the sub-watershed at a landscape scale, it also presents limitations, as previous biotope mapping studies 174 emphasize the importance of ground verification to confirm vegetation conditions, land cover classifications, and 175 microclimatic variation. 176 177 The accuracy of results may be affected by factors such as satellite resolution, seasonal variations in land surface 178 temperature, and the influence of high-rise structures on thermal readings in the dense urban districts. 179 180 III. Results and Analysis 181 182

3.1 Soil Map 183 The soil map reveals a mix of clay, clay loam, clay loam adobe, silt loam, and several areas labeled as undefined soil. Clay 184 and Clay Loam Adobe soils dominate the portions of the site, particularly in built-up districts. Although clay-based soils

185 retain moisture, its infiltration potential becomes limited when sealed by pavement, which contributes indirectly to higher 186 surface temperatures. Clay loam and silt loam soils, still seen on the built-up areas, appear lesser on the northeastern 187 region of the site. These soil types indicate opportunities for strengthening cooling vegetation in parks, roadside planting 188 strips, and remaining open areas. Although soil type has less influence on thermal behavior than land cover, it still 189 provides important insight into where cooling-oriented planting is feasible. 190 191

Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through Biotope Mapping Aquino 6 1 MUHON: A Journal of Architecture, Landscape Architecture and the Designed Environment University of the Philippines College of Architecture Issue No. _ 192

Figure 2. Soil Type Map 193 194 3.2 Landform map 195 The landform map shows that the study area is predominantly level terrain, with smaller portions classified as rolling, 196 undulating, and mountainous. A distinct linear riverbank zone follows the alignment of the Pasig River. This topographic 197 pattern reflects the condition of the site as a low-lying sub-watershed, where surface runoff naturally flows toward the 198 Pasig River. 199 200 In relation to urban heat, level built-up areas frequently exhibit elevated land surface temperatures because of extensive 201 impervious surfaces and limited airflow. Meanwhile, rolling and undulating pockets, although small in extent, can 202 influence micro-level ventilation. Riverbank landforms also present natural linear pathways that may function as potential 203 cooling corridors once supported with adequate vegetation. 204 205 206 Figure 3. Landform Map. 207 208 3.3 Landcover Map 209 The land cover map indicates that the study area is primarily built-up, reflecting the presence of Bonifacio Global City and 210 adjacent high-density barangays. Green spaces occur as isolated patches, with rangeland and other vegetated areas 211 appearing in fragmented clusters. Water cover consists almost entirely of the Pasig River. 212 213 The overwhelming presence of built-up surfaces makes the area highly susceptible to surface urban heat

island formation. 214 Fragmented green spaces limit the development of larger cooling cores and reduce ecological connectivity. The few 215 existing green patches, such as small parks and open spaces, offer localized cooling benefits but remain insufficient for 216 broader thermal mitigation. 217

Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through Biotope Mapping Aquino 7 **1** MUHON: A Journal of Architecture, Landscape Architecture and the Designed Environment University of the Philippines College of Architecture Issue No. _ 218

Figure 4. Landcover Map 219 220 3.4 Biotope Map 221 A total of twenty-one biotopes were identified within the 979.12-hectare sub-watershed, revealing a landscape 222 overwhelmingly dominated by built-up surfaces. Natural and semi-natural green biotopes appear only in small and 223 scattered patches throughout the study area. 224 225 Level Green Spaces consist of three biotope types and cover a combined 20.58 hectares, equivalent to only 2.10% of the 226 sub-watershed. These include Level Green Space Clay (8.41 ha, 0.89%), Level Green Space Clay Loam Adobe (8.01 ha, 227 0.85%), and Level Green Space Undefined Soil (4.16 ha, 0.44%). These biotopes appear primarily in parks, planted open 228 areas, and isolated pockets of vegetation within the built-up zone. 229 230 Undulating Green Spaces are represented by a single biotope, Undulating Green Space Clay Loam Adobe, covering 2.66 231 hectares or 0.28% of the study area. Although very limited in extent, this biotope provides vegetated structure along 232 slightly elevated topography and contributes localized cooling within its immediate surroundings. 233 234 Rangeland Biotopes form the largest green biotope category, with a combined area of 28.94 hectares or 2.95% of the study 235 site. These include Level Rangeland Clay (25.92 ha, 2.75%), Level Rangeland Undefined Soil (1.45 ha, 0.15%), and 236 Undulating Rangeland Clay (1.57 ha, 0.17%). Despite their relatively small coverage, these rangeland biotopes exhibit 237 higher vegetative complexity and represent some of the most valuable cooling areas within the sub-watershed. 238 239 In contrast, built-up biotopes occupy

more than 926 hectares, representing over 94% of the entire sub-watershed. The 240 largest built-up category is Level Built-up Clay, which covers 398.26 hectares or 42.28% of the total area. This is followed 241 by Level Built-up Clay Loam Adobe with 283.94 hectares (30.14%) and Level Built-up Undefined Soil with 59.29 hectares 242 (6.29%). Other built-up categories include Level Built-up Clay Loam (35.41 ha, 3.76%) and Level Built-up Silt Loam (9.50 243 ha, 1.01%), further emphasizing the dominance of impervious surfaces. 244 245 Additional built-up biotopes occur along varying terrain, including Rolling, Undulating, and Mountainous Built-up types. 246 These biotopes cover smaller areas, such as Rolling Built-up Clay (5.08 ha, 0.54%) and Mountainous Built-up Clay (1.09 ha, 247 0.12%), along with several Undulating Built-up variants ranging from 6.21 to 48.00 hectares. Although these categories 248 reflect elevation changes near the watershed boundaries, they remain highly urbanized and maintain minimal vegetation 249 presence. 250 251 Riverbank Built-up biotopes, covering 3.74 hectares (0.39%), represent hardened edges of the Pasig River, including Clay 252 Loam Adobe and Undefined Soil variants. These units exhibit low habitat scores due to sparse riparian vegetation and 253 reflect a heavily engineered river corridor with limited natural cooling capacity. 254 255 With this, the biotope distribution shows that the sub-watershed is a densely urbanized landscape with very limited 256 vegetated structure. Built-up biotopes dominate the area both spatially and functionally, while green biotopes remain 257 small, isolated, and fragmented. This pattern highlights the urgent need to strengthen ecological connectivity and develop 258 new corridors to mitigate the intense urban heat conditions observed in the study area. 259

Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through

Biotope Mapping Aquino 8 **1** MUHON: A Journal of Architecture, Landscape Architecture
and the Designed Environment University of the Philippines College of
Architecture Issue No.

_ 260 261 Figure 5. Biotope Map 262 263 Table 4. Biotope Matrix. 264 Code Landcover

Landform Soil Type Biotope Type B-L-C BUILT UP LEVEL CLAY Level Built-up Clay B-L-CL BUILT UP LEVEL CLAY LOAM Level Built-up Clay Loam B-L-CLA BUILT UP LEVEL CLAY LOAM ADOBE Level Built-up Clay Loam Adobe B-L-SL BUILT UP LEVEL SILT LOAM Level Built-up Silt Loam B-L-UND BUILT UP LEVEL UNDEFINED SOIL Level Built-up Undefined Soil B-R-CLA BUILT UP RIVERBANK CLAY LOAM ADOBE Riverbank Built-up Clay Loam Adobe B-R-UND BUILT UP RIVERBANK UNDEFINED SOIL Riverbank Built-up Undefined Soil B-RL-C BUILT UP ROLLING CLAY Rolling Built-up Clay B-RL-CLA BUILT UP ROLLING CLAY LOAM ADOBE Rolling Built-up Clay Loam Adobe B-U-C BUILT UP UNDULATING CLAY Undulating Builtup Clay B-U-CL BUILT UP UNDULATING CLAY LOAM Undulating Builtup Clay Loam B-U-CLA BUILT UP UNDULATING CLAY LOAM ADOBE Undulating Builtup Clay Loam Adobe B-U-UND BUILT UP UNDULATING UNDEFINED SOIL Undulating Builtup Undefined Soil B-M-C BUILT UP MOUNTAINOUS CLAY Mountainous Builtup Clay G-L-C GREEN SPACE LEVEL CLAY Level Green Space Clay G-L-CLA GREEN SPACE LEVEL CLAY LOAM ADOBE Level Green Space Clay Loam Adobe G-L-UND GREEN SPACE LEVEL UNDEFINED SOIL Level Green Space Undefined Soil G-U-CLA GREEN SPACE UNDULATING CLAY LOAM ADOBE Undulating Green Space Clay Loam Adobe R-L-C RANGELAND LEVEL CLAY Level Rangeland Clay R-L-UND RANGELAND LEVEL UNDEFINED SOIL Level Rangeland Undefined Soil R-U-C RANGELAND UNDULATING CLAY Undulating Rangeland Clay

265 3.5 Land Surface Temperature Map 266

Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through

Biotope Mapping Aquino 9 ¹ MUHON: A Journal of Architecture, Landscape Architecture and the Designed Environment University of the Philippines College of Architecture Issue No. _ The

Land Surface Temperature map shows clear temperature variation within the study area, with values ranging from 267 approximately 37.08°C to 38.91°C. The highest temperatures appear in the most intensely built-up portions of the sub268 watershed, particularly in

areas with limited vegetation. These locations contain large expanses of impervious surfaces, 269 minimal tree cover, and dense high-rise development, all of which contribute to elevated surface temperatures. Moderate 270 temperatures occur in built-up zones that contain small vegetated patches or cooling cores. However, their influence 271 remains limited due to their small size and fragmented distribution. 272 273 274 Figure 6. Land Surface Temperature Map 275 3.6 Ecological Management Map 276 The ecological assessment revealed clear differences in cooling value across the fifty-one (51) biotope units, shaped by 277 variations in land cover, vegetation structure, soil type, and urban density. The creative management (0–5 points) 278 represent the lowest scoring units, concentrated in the most densely built-up portions. Moreover, their low Period of 279 Development and Habitat scores indicate the absence of meaningful ecological structure, supporting the recommendation 280 to create new cooling spaces. These biotopes exhibit the greatest potential for transformative cooling improvements. 281 282 Next, the improvement management (6–10 points) shows moderate ecological value, typically consisting of areas where 283 vegetation exists but remains insufficient, fragmented, or weakly connected. These include landscaped areas and isolated 284 green pockets; their moderate scores indicate that these biotopes provide some cooling benefits but require enhancement 285 to maximize their ecological function. 286 287 Only a few biotope units qualified under the conservation management (11–15 points). These include rangeland patches 288 and selected green spaces with more mature vegetation, greater habitat complexity, and relative rarity in the urban 289 landscape. Although they cover only a small portion of the sub-watershed, these biotopes serve as important cooling cores 290 that maintain ecological function and provide essential thermal relief. 291 292 Overall, the ecological management assessment shows that most of the sub-watershed falls under Create and Improve 293 management, indicating widespread heat vulnerability and limited vegetation. Only a few biotopes qualify for Conserve 294 management, emphasizing the scarcity of high-value cooling areas. This distribution highlights the need to expand green 295 infrastructure, strengthen ecological connections, and protect the remaining vegetated

patches to build an effective 296 cooling network across the study area. 297 298

Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through
Biotope Mapping Aquino 10 **1** MUHON: A Journal of Architecture, Landscape
Architecture and the Designed Environment University of the Philippines College of
Architecture Issue No. _ 299

Figure 7. Ecological Management map 300 301 Table 5. Value Assessment Matrix. 302
Biotope Unit Area (ha) D A R H Total Management B-L-C-1 390.37 1 5 1 1 8 Improve B-
L-C-2 2.57 1 2 1 1 5 Create B-L-C-3 5.32 1 2 1 1 5 Create B-L-CL-1 31.19 1 3 2 3 9
Improve B-L-CL-2 4.22 1 2 2 3 8 Improve B-L-CLA-1 35.65 1 3 1 2 7 Improve B-L-CLA-2
1.34 1 2 1 2 6 Improve B-L-CLA-3 239.41 1 5 1 2 9 Improve B-L-CLA-4 7.54 1 2 1 2 6
Improve B-L-SL-1 9.5 1 2 5 1 9 Improve B-L-UND-1 13.96 1 3 2 3 9 Improve B-L-UND-2
8.39 1 2 2 3 8 Improve B-L-UND-3 36.94 1 3 2 3 9 Improve B-R-CLA-1 2.19 1 2 5 1 9
Improve B-R-UND-1 1.55 1 2 5 1 9 Improve B-RL-C-1 1.3 1 2 3 3 9 Improve B-RL-C-2
2.07 1 2 3 3 9 Improve B-RL-C-3 1.71 1 2 3 3 9 Improve B-RL-CLA-1 1.22 1 2 5 1 9
Improve B-U-C-1 1.67 1 2 1 1 5 Create B-U-C-2 1.13 1 2 1 1 5 Create B-U-C-3 4.44 1 2
1 1 5 Create B-U-C-4 1 1 2 1 1 5 Create B-U-C-5 7.6 1 2 1 1 5 Create B-U-C-6 13.4 1 3 1
1 6 Improve B-U-C-7 1.57 1 2 1 1 5 Create B-U-CL-1 1.81 1 2 3 1 7 Improve B-U-CL-2
5.51 1 2 3 1 7 Improve B-U-CLA-1 14.4 1 3 1 1 6 Improve B-U-CLA-2 1.74 1 2 1 1 5
Create B-U-CLA-3 16.73 1 3 1 1 6 Improve B-U-CLA-4 1.11 1 2 1 1 5 Create B-U-CLA-5
12.4 1 3 1 1 6 Improve

Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through
Biotope Mapping Aquino 11 MUHON: **1** A Journal of Architecture, Landscape
Architecture and the Designed Environment University of the Philippines College of
Architecture Issue No. _ B-U-

CLA-6 1.62 1 2 1 1 5 Create B-U-UND-1 6.21 1 2 5 1 9 Improve B-M-C-1 1.09 1 2 5 1 9
Improve G-L-C-1 1.00 1 1 2 2 6 Improve G-L-C-2 1.14 1 2 2 2 7 Improve G-L-C-3 1.31

1 2 2 2 7 Improve G-L-C-4 4.96 1 2 2 3 8 Improve G-L-CLA-1 1.21 1 2 2 2 7 Improve G-L-CLA-2 1.30 1 2 2 2 7 Improve G-L-CLA-3 1.41 1 2 2 2 7 Improve G-L-CLA-4 1.97 1 2 2 2 7 Improve G-L-CLA-5 2.12 1 2 2 2 7 Improve G-L-UND-1 4.16 1 2 5 3 11 Conserve G-U-CLA-1 1.23 1 2 3 2 8 Improve G-U-CLA-2 1.43 1 2 3 2 8 Improve R-L-C-1 25.92 2 3 5 4 14 Conserve R-L-UND-1 1.45 2 2 5 4 13 Conserve R-U-C-1 1.57 2 2 5 4 13

Conserve 303 3.7 Ecological Cooling Network Map 304 Firstly, the goal for creative management is to generate new nodes and corridors to reduce thermal intensity and 305 strengthen connectivity across the sub-watershed. Specific strategies are as follows: 306 307 3.7.1 Establishment of New Cooling Nodes. 308 Introducing pocket greens, planted open areas, or micro-cooling spaces that become new anchor points in the network 309 and reduce the distance between existing cooling cores. 310 311 3.7.2 Creation of New Cooling Corridors. 312 Adding street tree alignments along primary and secondary roads to form continuous vegetated pathways that link 313 fragmented cooling patches. 314 315 3.7.3 Reclamation of Idle or Impervious Spaces. 316 Transforming unused paved lots or excess road width into vegetated nodes that act as stepping stones within the cooling 317 network. 318 319 3.7.4 Introduction of Riparian Greening Along Engineered Riverbanks. 320 Placing modular planters, vertical greening, or linear planting strips along hardened Pasig River edges to initiate a cooling 321 corridor where continuous vegetation is otherwise not possible. 322 323 Secondly, the improvement management supports zones that require enhancement that function as effective corridors, 324 intermediate nodes, or transition areas. Specific strategies are as follows: 325 326 3.7.5 Canopy Expansion. 327 Increasing canopy cover along streets, pathways, and green edges to elevate their cooling function and improve corridor 328 continuity. 329 330 3.7.6 Enhancement of Fragmented Green Patches. 331 Upgrading isolated open spaces so they act as effective stepping stones that bridge cooling cores and other vegetated 332 areas. 333 334 3.7.7 Vegetated Buffer Enhancement Along Built Edges. 335 Adding linear planting zones along buildings, walkways, and parking lots to soften thermal boundaries and support 336 corridor formation. 337 338 3.7.8 Upgrading Existing Open Spaces into

Ecological Cooling Network Planning for the Bonifacio Global City Watershed Through
Biotope Mapping Aquino 12 1 MUHON: A Journal of Architecture, Landscape
Architecture and the Designed Environment University of the Philippines College of
Architecture Issue No. _

Transforming underperforming landscaped areas into stronger cooling pockets with multi-layer vegetation, enabling 340 them to serve as mid-point nodes in the network. 341 342
3.7.9 Incremental Riparian Vegetation Reinforcement. 343 Introducing or densifying
vegetation in accessible riverbank sections to improve the continuity and cooling function
of the 344 Pasig River corridor. 345 346 Lastly, conservation management is for primary
anchors of the system. The objective is to protect, maintain, and 347 strengthen existing
cores to ensure long-term thermal mitigation and ecological stability. 348 349 3.7.10
Habitat Maintenance and Structural Enhancement 350 Retaining existing vegetation while
adding depth through understory and midstory layers, improving their microclimate 351
function without altering the core structure. 352 353 3.7.11 Establishment of Protective
Ecological Buffers 354 Creating low-disturbance peripheral planting zones around
conserved areas to protect core vegetation and maintain the 355 stability of the cooling
node. 356 357 3.7.12 Integration as Primary Network Anchors 358 Designating conserved
biotopes as the main hubs within the ecological network and ensuring corridors and
improved 359 areas are oriented toward strengthening their connectivity. 360 361 362
Figure 8. Ecological Network map. 363 364 IV. Conclusion 365 As dense urban districts
continue to expand, highly built-up areas such as Bonifacio Global City and its surrounding
366 barangays become increasingly vulnerable to intensified urban heat conditions.
Through biotope mapping, the ecological 367 structure of these heat-prone environments
can be identified, allowing the development of a cooling network that 368 supports thermal
regulation and improves urban livability. 369 370 A total of twenty-one (21) biotope types
and fifty-one (51) biotope units were identified within the 979.12-hectare BGC 371 sub-

watershed. Green biotopes, including Level Green Spaces, Undulating Green Spaces, and Rangeland units, occupied 372 only a small portion of the site, while built-up biotopes dominated more than 94% of the area. Through biotope 373 assessment, the remaining green biotopes were found to have the highest ecological value and were designated as the 374 primary cooling cores of the ecological network. 375 376 The Pasig River corridor and vegetated segments along its banks formed the foundation of the cooling corridors, offering 377 the only continuous linear feature capable of supporting large-scale cooling across the study area. Meanwhile, scattered 378 patches of green space within the built-up matrix serve as cooling elements as well that can be strengthened to enhance 379 overall network connectivity. 380 381 Building on these findings, three management strategies were recommended for the sub-watershed: Creative 382 Management for heat-intensive zones with minimal vegetation, Improvement Management for areas with moderate 383 cooling function, and Conservation Management for the remaining high-value green spaces. Together, these strategies 384

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informed the formulation of the Ecological Cooling Network Plan, which seeks to establish connected cooling routes, 385 reinforce existing vegetated areas, and introduce new cooling nodes to mitigate heat stress across the urban landscape. 386 387 In moving forward, it is recommended that future research incorporate field validation to support and refine the remote388 sensing-based assessments used in this study. Strengthening collaboration with local planners and community 389 stakeholders would also help translate the Ecological Cooling Network Plan into actionable urban interventions. 390 Moreover, expanding the analysis to adjacent sub-watersheds and integrating additional spatial metrics could further 391 enhance long-term strategies for urban heat mitigation in

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421–422

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