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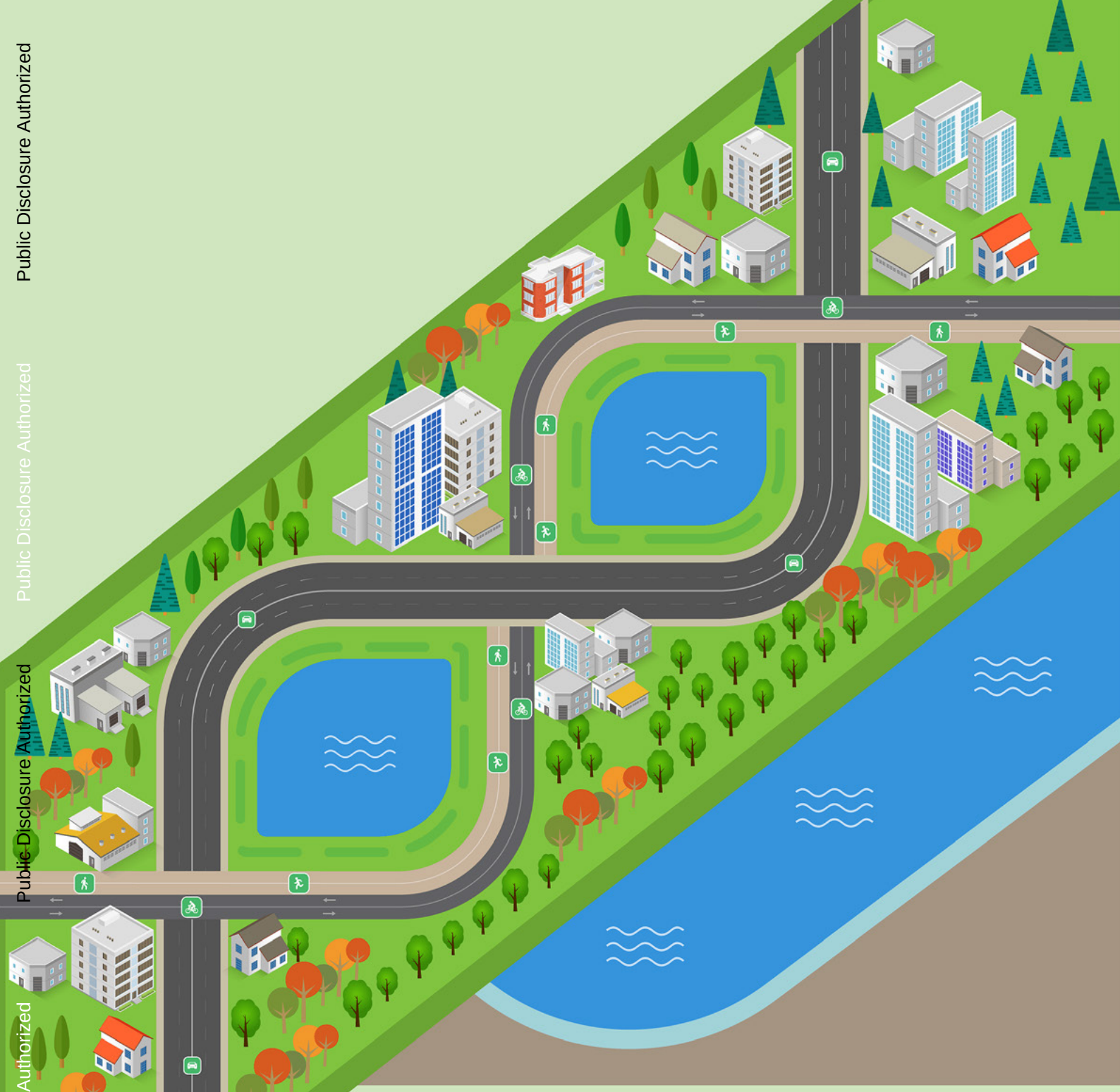

GREEN CORRIDOR PLANNER GUIDELINES

Almaty Agglomeration, Kazakhstan

June 2025

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About Green Corridor Planner Guidelines, Almaty Agglomeration, Kazakhstan

Green Corridor Planner Guidelines, Almaty Agglomeration, Kazakhstan, were developed as an essential complementary resource to the *Greenway to Konaev: Action Plan for a Green Corridor in Almaty Agglomeration, Kazakhstan (GKAP)*, providing technical approaches and tools to support the design and implementation of this ambitious green infrastructure project. These novel guidelines provide an actionable framework to guide Almaty City and Almaty Agglomeration in the planning and implementation of sustainable green infrastructure, beginning with the GKAP. This initiative, led by Akimat of Almaty Oblast, aims to establish a green corridor along the Almaty-Konaev highway to the Kapchagai Reservoir as part of a broader *Green Network for Almaty Agglomeration* vision. The vision is to create an interconnected network of green spaces along major rivers, transport corridors, and recreational routes — from the foothills of Almaty to the Kapchagai Reservoir — to address environmental challenges and support sustainable regional growth.

The Almaty-Kapchagai landscape presents a challenging climate, ranging from semi-arid to arid zones, requiring specialized strategies for restoration and ecological enhancement. The guidelines offer a progressively structured suite of nature-based solutions (NBS), tailored approaches, and technical tools to advance green corridor development. These solutions range from basic linear green corridors, designed to increase canopy cover, to more complex ecological restoration and landscape linkage techniques, all aimed at enhancing forest and green cover to reinforce ecological integrity and environmental resilience. In addition to the GKAP, the *Almaty Tree Management Plan* (Almaty TMP) was established to provide Akimat of Almaty and Akimat of Almaty Oblast with detailed technical guidance on species selection, planting, and maintenance, along with historical context and detailed analysis of indigenous and exotic species within Almaty and surrounding areas. The detailed technical information in the Almaty TMP provides additional support to the use of the guidelines to design and implement green corridors in the Almaty region.

Together, these resources — this report, the GKAP, and the Almaty TMP — form a comprehensive toolkit for mitigating desertification, landscape degradation, and climate change impacts across the Almaty region. Supported by the World Bank's *Resilient Landscapes in Central Asia Program*,[1] these resources provide essential, evidence-based approaches for establishing interconnected green corridors and enhanced tree management practices that will serve as a foundation for long-term environmental health and sustainable growth.

[1] https://www.worldbank.org/en/topic/environment/brief/climate-and-environment-program-in-central-asia#RESILAND.

Table of Contents

About Green Corridor Planner Guidelines, Almaty Agglomeration, Kazakhstan i
Acknowledgments vii
Abbreviations and Glossary of Terms viii
Executive Summary 1
1. Introduction 3
1.1. Urban and Landscape Resilience Challenges 3
1.2. Overview of Proposed Green Network for Almaty Agglomeration 4
1.3. Green Network Key Principles 5
1.4. The Benefits of Green Network Creation 9
1.5. Guidelines to Support the Design and Establishment of Green Corridors within the Green Network 9
1.6. Checklist for Decision-Making 10
2. Approaches and Tools for Creating Green Corridors 11
2.1. User's Guide for the Chapter 11
2.2. Illustration of Approaches and Recommendations 18
2.3. Increased Tree Canopy Cover Approach 21
2.4. Ecological Restoration and Enhancement Approach 44
2.5. Green Linkages Approach 72
2.6. Recreation Development Approach 77
2.7. Harvesting of Additional Water Resources Approach 91
References 98

ANNEXES

Annex 1. Analytical Assessments 104
Annex 2. Best World Practices for Creating Recreational Routes 108

TABLES

Table 1. Approaches' summary table 19
Table 2. Species diversity rules for tree planting 22
Table 3. Recommended minimum parameters of tree planting strips 23
Table 4. Species diversity rules for tree planting 27

FIGURES

Figure ES.1. A snapshot of green corridor development approaches 2
Figure 1. Rising air temperature 3
Figure 2. Floods in Kazakhstan 3
Figure 3. Street flooding in Kazakhstan 3
Figure 4. Shallowing of water bodies 3
Figure 5. Visualization of 'The Greenway to Konaev' green corridor 5

Figure 6. The proposed vision of Green Network for Almaty Agglomeration 6
Figure 7. Visualization of interconnected green corridors into network along a river and a road buffer 7
Figure 8. Steps to create a green corridor within a green network 8
Figure 9. Information on each approach and its tools is organized to provide an understanding of effective integration into a context 12
Figure 10. Approaches to Creating Green Corridors 13
Figure 11. Challenges that could be mitigated by all approaches 13
Figure 12. Benefits related to approaches 13
Figure 13. Ecosystem-based practices in the tool's description 14
Figure 14. Geographic areas icons 14
Figure 15. Spatial zones icons 15
Figure 16. Illustration of a common section for application of spatial Zones 2.1 and 2.2 15
Figure 17. Illustration of a common section for application of spatial Zones 5.1 and 5.2 16
Figure 18. Land use icon 17
Figure 19. Technical specifications icon 17
Figure 20. Illustration of approaches 18
Figure 21. Challenges mitigated by the Increased Tree Canopy Cover Approach 21
Figure 22. Benefits of the Increased Tree Canopy Cover Approach 21
Figure 23. Tools for the Increased Tree Canopy Cover Approach 21
Figure 24. An urban street in Canberra, Australia 22
Figure 25. Single tree planting on the banks of Bolshaya Almatinka 25
Figure 26. Visualization of single tree planting on the banks of Bolshaya Almatinka 26
Figure 27. A group of different sorts of trees in Berliner park 26
Figure 28. Group tree and shrubs planting in the Esentai valley 28
Figure 29. Visualization of group tree and shrubs planting in the Esentai valley 29
Figure 30. A riparian forest buffer grows along a small creek in Pennsylvania, where it has been planted to help stabilize streambanks, stop upland nutrient pollution from entering the stream, and shade and cool the water 29
Figure 31. Riparian buffer vegetation belts 32
Figure 32. The urban food forest at Browns Mill in Atlanta, GA 32
Figure 33. A public food forest near Esentai 34
Figure 34. Windbreaks in North Dakota 35
Figure 35. Illustration of the principles of wind, sand, and snow protection 36
Figure 36. Planting windbreaks along the Almaty-Konaev highway 37
Figure 37. Planting between tree alleys 38
Figure 38. Alley plantings near Malaya Almatinka 40
Figure 39. The distance between tree rows depends on the growing crops and the harvesting equipment, and the change of crops during tree growth must be taken into account 40
Figure 40. Silvopasture can help reduce heat stress, which improves animal performance and well-being 41
Figure 41. A silvopasture along the Malaya Almatinka River 43
Figure 42. Typical section of a silvopasture 43

Figure 43. Challenges mitigated by the Ecological Restoration and Enhancement Approach....44
Figure 44. Benefits of the Ecological Restoration and Enhancement Approach....44
Figure 45. Tools for the Ecological Restoration and Enhancement Approach....44
Figure 46. Tugai forests downstream of the Syr Darya river, Kazakhstan....45
Figure 47. Malaya Almatinka reforestation....47
Figure 48. The forest upstream of the Esentai....47
Figure 49. Slope reforestation....49
Figure 50. Visualization of the slope reforestation....49
Figure 51. Stream restoration in Singapore....50
Figure 52. Riprap with planting holes....51
Figure 53. Coir mats and rolls....51
Figure 54. J-hook vane (in plan)....52
Figure 55. Full restoration of the Malaya Almatinka valley....53
Figure 56. Fragment of the naturalization of the river, applying the techniques described in the 'How?' section....54
Figure 57. Reconstructed channel of the Malaya Almatinka....54
Figure 58. Partial re-naturalization project for Permanente Creek in Canada: comparison between the current situation (top picture) and the conceptual rendering (bottom picture).....55
Figure 59. A successful compromise in the upper Esentai - the riverbank is made with gabions; the other is naturally preserved with the use of a rock outline....56
Figure 60. Restoration of one bank of the Malaya Almatinka river....57
Figure 61. Natural riverbank protection with riprap....57
Figure 62. Los Angeles River Revitalization Master Plan....58
Figure 63. The Cheonggyecheon River, Seoul, Republic of Korea, is a good example of artificial riverbed improvement in an urban environment....59
Figure 64. Berm creation during construction and one year later, showing vegetation colonization on River Somer in Midsomer Norton in Somerset, England....59
Figure 65. Even concreted, the Big Almatinka forms shallows like a natural river....60
Figure 66. Embankments of Esentai river: solid concrete slope and vegetated concrete slope....60
Figure 67. The green wall along the recreational route on Malaya Almatinka river....61
Figure 68. Improvement of the Bolshaya Almatinka artificial riverbed....62
Figure 69. Changing the profile of the slopes from a diagonal to a straight wall to make more space for pedestrian paths along the waterfront....62
Figure 70. Van Der Donck Park, City of Yonkers, New York, USA.....63
Figure 71. Culverted Zharbulak river under the new residential complex 'Europolis' on Omarova Street....63
Figure 72. The opening of Boralday River....64
Figure 73. Woodberry Wetlands reedbeds during and after installation. London, UK.....65
Figure 74. Aquatic biotope near the metal bank....66
Figure 75. Shallows created with aquatic vegetation on Sairan Reservoir....67
Figure 76. (a) A good example of a diverse ecosystem by the waterfront, represented by grasses, shrubs, trees, flowers—a home for animals and birds. (b) A poor example of traditional row planting of trees, without different plant tiers....68

Figure 77. Bird box 69
Figure 78. Bat box 69
Figure 79. Insect hotel 69
Figure 80. Forest biotope created in the riparian buffer of Malaya Almatinka River 71
Figure 81. Challenges mitigated by the Green Linkages Approach 72
Figure 82. Benefits of the Green Linkages Approach. 72
Figure 83. Tools for the Green Linkages Approach 72
Figure 84. A good example of an urban boulevard: Bukhar Zhyrau Boulevard, 32 m long, connecting Satpayev Square and Esentai Embankment 73
Figure 85. Utepova Street boulevard 74
Figure 86. An example of a system of small squares, green spaces, and parks acting as a green link between two major green cores: Wanstead Flats and Olympic Park in the Lea Valley, London, England 75
Figure 87. The park system between Baum Grove and the Malaya Almatinka river valley 76
Figure 88. Challenges mitigated by the Recreation Development Approach 77
Figure 89. Benefits of the Recreation Development Approach 77
Figure 90. Tools for the Recreation Development Approach 77
Figure 91. A good example: the outdoor training paths on Malaya Almatinka 78
Figure 92. 'Katok Medeu–Konaev' route map 80
Figure 93. Fragment of the connection of the bicycle path 'Katok Medeu-Konaev' to the pilot project 'Greenway to Kapchagai' 80
Figure 94. Tunnel under the street for the bicycle path, a fragment of the 60-meter tunnel for the RijnWaalpad recreational path, The Netherlands 81
Figure 95. Good example: The intersection of the Small Almatinka Terrenekur and Al-Farabi Avenue 82
Figure 96. Good example: Terrenekur crossing on the Esentai river with an engineering structure 82
Figure 97. Creation of a path along Esentai under the bridge structure on Timiryazev Street 83
Figure 98. Construction of smooth lowering of embankment level; minimum height from pavement floor to top of bridge structure - 2.5 m; vertical wall landscaping 83
Figure 99. Steps to the water can be formed either through reconstruction of the bank slope (left bank) or attached to the structure (right bank), Cheonggyecheon Canal, Seoul 84
Figure 100. Before - water access is closed 85
Figure 101. Post-conversion of part of the concrete slope on the Bolshaya Almatinka into a slope to the water with additional landscaping of the steps—if possible, retaining the shoals with the addition of riprap and aquatic vegetation 85
Figure 102. Good example of picnic area near the Prohodnaya river, Qalalyq Ferma, Almaty, Kazakhstan 86
Figure 103. Types of short-term rest areas 87
Figure 104. Example of a rest stop with basic infrastructure 87
Figure 105. Example of a picnic area 88
Figure 106. Example of a playground rest stop 88
Figure 107. Example of a sports ground rest stop 89
Figure 108. Example of a dog ground 89
Figure 109. Rest areas along the recreational route 90

Figure 110. Challenges mitigated by the Harvesting of Additional Water Resources Approach 91
Figure 111. Benefits of the Harvesting Additional Water Resources Approach 91
Figure 112. Tools for the Harvesting of Additional Water Resources Approach 91
Figure 113. Rainwater harvesting from the roof through a filter into an underground tank 92
Figure 114. A barrel for small storage capacity 93
Figure 115. Cisterns for bigger storage capacity 93
Figure 116. Water storage as an element of public space 93
Figure 117. Underground closed plastic tank 94
Figure 118. Storage system under buildings, for example, under an underground parking garage 94
Figure 119. Underground storage tank made of geocellular storage system - constructed below the sport field does not take valuable land, store rainwater from roofs and surface water runoff, which mitigates flooding 94
Figure 120. Gravity water intake system for collecting small amounts of water for local irrigation 95
Figure 121. Pumping rainwater harvesting system into an underground tank 95
Figure 122. Example of water square, a pond connected to rainwater harvesting systems, Potsdamer Platz, Berlin, Germany 96
Figure 123. Open reservoir for rainwater storage at the Auezov Theatre Square 97
Figure A1.1. The consideration area of Almaty Agglomeration green network 104
Figure A1.2. Diagram of landscape zones of the territory 105
Figure A1.3. Water assets 106
Figure A1.4. Green assets 106
Figure A1.5. Recreational assets 106
Figure A1.6. Future Transformation 106
Figure A2.1. Route map 108
Figure A2.2. A bicycle route along the river Maas 108
Figure A2.3. Camping stop for an overnight stay along the way 108
Figure A2.4. Route map 109
Figure A2.5. Bicycle lane separated from the roadway by a strip of greenery 109
Figure A2.6. Viewpoints along the route 109
Figure A2.7. Route map 110
Figure A2.8. Part of the route runs along the seashore 110
Figure A2.9. A bicycle parking lot is placed at the point where the route connects to the settlements 110

Acknowledgments

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Abbreviations and Glossary of Terms

Abbreviations

ESG	Environmental, social, and governance
GKAP	Greenway to Konaev Action Plan for a Green Corridor in Almaty Agglomeration, Kazakhstan
NBS	Nature-Based Solutions
NTFP	Non-timber Forest Products
RESILAND CA	Resilient Landscapes in Central Asia Program
TMP	Tree Management Plan

Glossary of Terms

Agroforestry practices — the intentional combination of agriculture and forestry to create productive and sustainable land use practices. These practices take advantage of the interactive benefits from growing trees and shrubs together with crops and/or livestock.[2]

Anthropogenic load/pressure — a human impact that leads to undesirable changes or destruction of natural ecosystems (Dogadina et al. 2022).

Barchan — a crescent-shaped shifting sand dune, convex on the windward side and steeper and concave on the leeward.[3]

Biodiversity — diversity of plant and animal life, especially as represented by the number of extant species.[4]

Biotope — an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals (Iwasawa 2005).

Canalization of riverbeds — a set of measures are presented to control downcutting of riverbeds caused by scouring, such as construction of water retaining dams, riprap protection of riverbeds, liner protection of riverbeds, and artificial adding of sediment (Guo 2002).

Carbon certification — a voluntary EU-wide framework to certify carbon removals generated in Europe. It sets out criteria to define high-quality carbon removals and the process to monitor, report, and verify the authenticity of these removals. With this certification framework, the aim is to boost innovative carbon removal technologies and sustainable carbon farming solutions while fighting greenwashing.[5]

[2] For an overview of agroforestry practices, see the United States Department of Agriculture (USDA) website: Agroforestry Practices.

[3] Oxford Dictionary. *Barchan definition:* https://www.oed.com/search/dictionary/?scope=Entries&q=barchan&tl=true.

[4] Oxford Dictionary. *Biodiversity definition:* https://www.oed.com/dictionary/biodiversity_n?tab=factsheet#20265023.

[5] For an overview of how certification works, see the Climate Action of European Commission website: Carbon Removal Certification — European Commission.

Carbon credit — a transferable financial instrument (that is, a derivative of an underlying commodity) certified by governments or independent certification bodies to represent an emission reduction that can then be bought or sold (Fredman and Phillips 2022).

Climate change — the significant variation of average weather conditions becoming, for example, warmer, wetter, or drier-over several decades or longer. It is the longer-term trend that differentiates climate change from natural weather variability.

Dacha — Russian: дача, IPA: ['datɕə] — a seasonal or year-round second home, often located in the exurbs of post-Soviet countries.[6]

Ecological cores — large, least fragmented green areas including city parks, forested foothill areas, and wide green valleys in the steppe and desert zones. These core areas function as important ecological hubs and recreational spaces (Dramstad, Olson, and Forman 1996).

Ecosystem-based practices — the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change; these approaches may include sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities (Cohen-Shacham et al. 2019).

Environmental, social, and governance — a set of aspects considered when investing in companies, that recommends taking environmental issues, social issues, and corporate governance issues into account (Gelles 2023).

Flooding — a situation in which an area is covered with water, especially from rain.[7]

Fragmentation of green cover — splitting of vegetated areas into smaller and isolated patches as a result of urban sprawl which is considered as a threat to ecosystem functions, local biodiversity, and other ecological services (Fang et al. 2021).

G4 City — a smart city consisting of four modern themed districts located along the Almaty-Konaev highway.[8]

Geographic areas — portions of the Earth's surface that are broadly divided by physical characteristics (physical geography), human impact characteristics (human geography), and the interaction of humanity and the environment (environmental geography) (Bailey 1996).

Green areas — public areas located within the boundaries of urban and rural settlements, formed by areas of natural and artificially created landscapes (parks, gardens, squares, park alleys, boulevards, and other areas of landscaping, including with permeable pavement), providing recreational connection of residential, public, and business and other functional zones, with at least 70 percent of the surface occupied by green plantings and other vegetation cover (Hudeková 2018).

Green corridors — linear links consisting of vegetation strips and bicycle trails, providing ecological and recreational connectivity (Dramstad, Olson, and Forman 1996).

Green infrastructure — a strategically planned network of natural and seminatural areas with other environmental features, designed and managed to deliver a wide range of ecosystem services, while also enhancing biodiversity.[9]

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6 *Brockhaus Enzyklopädie* (in German). 1995. Vol. 26. Mannheim: F. A. Brockhaus.

7 Cambridge Dictionary. *Flooding definition:* FLOODING | English meaning — Cambridge Dictionary.

8 Caspian group: G4 City.

9 For an overview of green infrastructure, see the Environment Section of European Commission website: Green infrastructure — European Commission.

Groundwater infiltration — groundwater is derived from rain and melting snow that percolate downward from the surface; it collects in the open pore spaces between soil particles or in cracks and fissures in bedrock. The process of percolation is called infiltration (Kovalevski 1992).

Habitat connectivity — the network of corridors that links isolated patches of habitat, which allows organisms to move through an area.[10]

Habitat fragmentation — describes the emergence of discontinuities (fragmentation) in an organism's preferred environment (habitat), causing population fragmentation and ecosystem decay (Fahrig 2019).

Heat islands — urbanized areas that experience higher temperatures than outlying areas. Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies.[11]

Land use — the purpose for which an area of land is being used, such as residential, agricultural, commercial, retail, or industrial. Also known as land cover or land utilization.[12]

Meanders — a series of regular sinuous curves in the channel of a river or other watercourse. Meanders are a result of the interaction of water flowing through a curved channel with the underlying riverbed (Neuendorf, Mehl Jr., and Jackson 2005).

Microclimate — the suite of climatic conditions measured in localized areas near the earth's surface. These environmental variables which include temperature, light, wind speed, and moisture provide meaningful indicators for habitat selection and other ecological activities (Fath 2018).

Mudflow — a mass of water and fine-grained earth materials that flows down a stream, ravine, canyon, arroyo, or gulch. To be considered a mud flow, more than half of the particles must be sand sized or smaller that can flow very rapidly. A mudflow is the sandy, more water-saturated analog of a debris flow.[13]

Natural ecosystem — a community of living and non-living entities that occurs freely in nature. All components interact as a combined unit through physical, chemical, and biological processes. The distinguishing factor of natural ecosystems from other ecosystems is that they are completely natural.[14]

Nature-based solutions (NBS) — approaches that use nature and natural processes for delivering infrastructure, services, and integrative solutions to meet the rising challenge of urban resilience (World Bank 2021a).

Non-timber forest products (NTFP) — useful foods, substances, materials, and/or commodities obtained from forests other than timber. Harvest ranges from wild collection to farming. They typically include game animals, fur-bearers, nuts, seeds, berries, mushrooms, oils, sap, foliage, pollarding, medicinal plants, peat, mast, fuelwood, fish, insects, spices, and forage (Ministry of Forests and Range 2008).

Passive reforestation — or ***Rewilding*** — land preservation for the forests to grow back and a way to restore montane forest in huge areas where classic reforestation or planting can be difficult or too expensive (Montague 2020).

[10] A Dictionary of Environment and Conservation (1 ed.). *Habitat connectivity definition:* Habitat connectivity — Oxford Reference.

[11] EPA (U.S. Environmental Protection Agency). *Heat Island Effect definition:* Heat Island Effect | US EPA.

[12] A Dictionary of Environment and Conservation (1 ed.): Land use definition: Land Use — Oxford Reference.

[13] Colorado geological survey. *Debris and Mud Flows:* Debris and Mud Flows — Colorado Geological Survey.

[14] European Environment Agency (EEA) Glossary. *Natural Ecosystems definition:* natural ecosystem — European Environment Agency.

Pocket park — also known as a ***parkette***, ***mini-park***, ***vest pocket par***k, or ***vesty park*** — a small park accessible to the general public. While the locations, elements, and uses of pocket parks vary considerably, the common defining characteristic of a pocket park is its small size. Typically, a pocket park occupies one to three municipal lots and is smaller than 0.5 hectares (1 acre) (Faraci 1967).

Rehabilitation — a complex of measures to ensure the conservation of natural ecosystems, their rational and non-exhaustive use, and their protection and regeneration (Meshkov et al. 2009).

Re-naturalization — *of the riverbeds* — removing some concrete or inert constructions in the riverbed and on riverbanks and replacing them with vegetation and vegetative structures to avoid riverbed and riverbank damages and restore biodiversity.[15]

Riparian buffer — an area adjacent to a stream that contains a combination of trees, shrubs, and/or other perennial plants and is managed differently from the surrounding landscape, primarily to provide conservation benefits (MacFarland, Straight, and Dosskey 2019).

Riparian forests — native floodplain forest ecosystems called ***Tugai forests*** that are typical for river floodplains in arid zones of Kazakhstan (Borissova, Nakladal, and Nurgaliyev 2017).

Riverbank erosion — the wearing away of the banks of a stream or river. This is distinguished from erosion of the bed of the watercourse, which is referred to as scour. The roots of trees growing by a stream are undercut by such erosion. As the roots bind the soil tightly, they form abutments which jut out over the water. These have a significant effect upon the rate and progress of the erosion (Rutherford and Grove 2004).

Stakeholders — employees, investors, or customers who are involved in or benefit from a project and have an interest in its success.[16]

Succession — same as passive reforestation.

Sustainable — causing, or made in a way that causes, little or no damage to the environment and therefore able to continue for a long time.[17]

Tree Management Plan (TMP) — a tailored plan that guides tree care professionals to proactively and effectively manage and provide for maximum, long-term benefits to the local community. The plan provides different resources, such as plans and tools, to proceed with the planning steps. A TMP should be implemented in combination with an Urban Forest Management Plan (UFMP) which includes a vision for the urban forest, inventories and assessments of the current status of the urban forest, definition of a strategic plan based on identified needs, and an implementation and monitoring plan (California Urban Forest Council 2016) for optimal forest management in cities.

Urban tree canopy (UTC) — the layer of leaves, branches, and stems that cover the ground when viewed from above. Tree canopy is generally taller than 10–15 feet (Raciti et al. 2006).

Urbanized cores — a human settlement or its part with a high population density and an infrastructure of built environment (Morris 1972).

Water regime — a set of indicators such as timing and predictability, frequency, duration, extent and depth, variability, and rate of change of the water source (Campbell, Boulton, and Brock 2000).

Water resource management — the deliberate management (protection, allocation, and development) of water resources to benefit people and/or the environment.[18]

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[15] For a general overview of riverbed re-naturalization, see the Natural Water Retention Measures (NWRM) website: Stream bed re-naturalisation: Natural Water Retention Measures.

[16] Cambridge dictionary. *Stakeholder definition*: STAKEHOLDER | English meaning — Cambridge Dictionary.

[17] Cambridge dictionary. *Sustainable definition*: SUSTAINABLE | English meaning — Cambridge Dictionary.

[18] A Dictionary of Environment and Conservation (1 ed.). *Water resource management definition*: https://www.oxfordreference.com/display/10.1093/oi/authority.20110803121304468.

Executive Summary

Green Corridor Planner Guidelines, Almaty Agglomeration, Kazakhstan were developed as recommendations to support the design and implementation of the Green Network for the Almaty Agglomeration, beginning with a pilot green corridor initiative The Greenway to Konaev.

Green Corridor Planner Guidelines, Almaty Agglomeration, Kazakhstan, is a comprehensive, practical guide designed to support the Almaty City and Almaty Oblast Akimats in planning and implementing green corridors for landscape restoration and enhanced climate resilience. As Kazakhstan's largest urban agglomeration,[19] Almaty spans a uniquely landlocked region with five distinct climatic zones—from arid deserts to high-altitude, snow-capped areas—presenting a complex environmental context for sustainable development. Facing unprecedented challenges from climate change, natural hazards (such as landslides, mudflows, and floods), heat stress, urbanization, and desertification, among others, the city of Almaty and the wider Almaty Agglomeration require robust, tailored, sustainable solutions. These guidelines serve as a vital resource for planners, foresters, policy makers, and community stakeholders, providing a structured framework for developing resilient green infrastructure across the region.

This resource offers a scalable set of strategically structured approaches and tools, specifically tailored to support green corridor development for landscape rehabilitation, ecological restoration, and enhancement across Almaty's semi-arid and arid landscapes. This strategic initiative is aimed at supporting government and interested stakeholders to enhance the urban, peri-urban, and rural landscapes through the establishment of interconnected green corridors, resulting in a comprehensive green network. These guidelines were initially conceptualized to meet the growing demand in the Almaty region for green corridors and interconnected green networks to support urban and landscape regeneration through greening and enhanced habitat connectivity. It was ultimately formalized as a supplementary resource to advance the *Greenway to Konaev Action Plan (GKAP),* a pilot initiative within the ambitious *Green Network for Almaty Agglomeration* vision. Established to support the implementation of the *GKAP* green corridor pilot, spearheaded by Akimat of Almaty Oblast, this comprehensive guideline has been expanded to provide practical, locally adapted approaches and tools for green corridor development across the broader Almaty Agglomeration.

Green Corridor Planner Guidelines, Almaty Agglomeration, Kazakhstan, is comprised of*:*

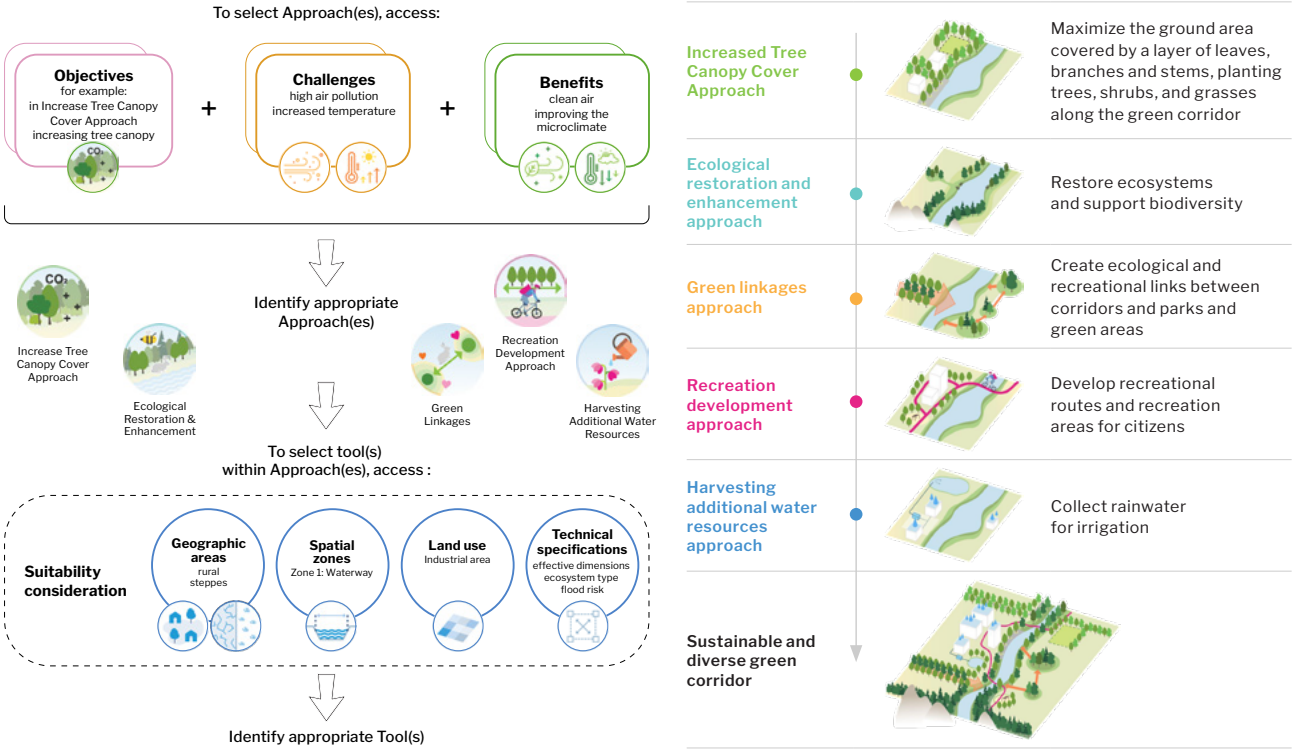
1. An introductory section containing:
   - Almaty City's and the agglomeration's resilience challenges
   - an overview of the green network vision, principles, and benefits
   - a general overview of the guidelines
   - a checklist for decision-making.
2. A detailed green corridor development approaches and tools section containing:
   - a user's guide
   - an illustration of approaches and guideline

[19] Nyussupova, G., A. Kalimurzina, R. Kelinbayeva, S. Kairova, and L. Kenespayeva. 2023. "Regional Features of Agglomeration and the Antidote to Almaty's Landlocked Condition." *In Border Urbanism. The Urban Book Series*, edited by Q. M. Zaman and G. G. Hall, 213–224. Springer, Cham. https://doi.org/10.1007/978-3-031-06604-7_12.

- Detailed green corridor development approaches, with their respective tools, including the following core thematic approaches:
  a. Increased tree canopy cover
  b. Ecological restoration and enhancement
  c. Green linkages
  d. Recreation development
  e. Harvesting of additional water resources.

The second section of the guideline offers comprehensive, step-by-step guidance on strategically envisioning, approaching, and designing green corridor initiatives. It assists users in identifying project objectives, including the specific challenges the initiative aims to address and the benefits it seeks to achieve. The guideline then presents a systematic suite of green corridor approaches and tools designed to incrementally enhance and optimize ecological, environmental, and human-centered integrity, ensuring the maximization of overall project benefits. A snapshot of the approaches can be found in the diagrams below.

Figure ES.1. A snapshot of green corridor development approaches.



Source: Original elaboration.

Each approach includes a series of customized tools that offer detailed descriptions, highlight co-benefits, and provide technical considerations and specifications. These tools cover essential aspects such as what and how to implement, and where the tool is applicable (including suitability considerations), supported by practical visualizations to guide users through the process.

Together with supplementary resources such as the GKAP and regional tree management plans, this guideline provides comprehensive insights into effective approaches and technical considerations for planning, designing, and implementing green corridors and sustainable green infrastructure across the Almaty region.

1. Introduction

1.1. Urban and Landscape Resilience Challenges

Almaty Agglomeration is a large territory in Central Asia, located in a region with a sharply continental climate characterized by cold winters and dry summers. The area of the agglomeration includes various ecological zones from deserts to mountain meadows and forests which create different microclimates and valuable landscapes. However, specific landscapes require tailored approaches: the mountains have a better microclimate, but there is a risk of landslides, and in the desert, it is important to consider the high level of aridity and possible summer droughts.

These risks are aggravated by the intensive urbanization in the region that aims to make the urban fabric more compact, reducing the proportion of the urban forest and increasing the urban heat island effect (Zakarin et al. 2022). Over the past five decades, the climate of Almaty Agglomeration has witnessed a shift toward aridity, which poses significant challenges to the region (World Bank 2021b).

Figure 1. Rising air temperature

The air temperature rises dramatically

Source: https://almaty.tv/news/obschestvo/1301-silnaya-dgara-v-almaty-v-dchs-obratilis-k-dgitelyam.

Figure 2. Floods in Kazakhstan

Landslides, mudflows, and floods are increasing

Source: https://floodlist.com/asia/kazakhstan-floods-1000-evacuated-almaty-region-july-2015.

Figure 3. Street flooding in Kazakhstan

The number of extreme weather events is growing

Source: https://www.kt.kz/rus/incidents/ulitsy_almaty_zatopilo_posle_livnya_1377933379.html.

Figure 4. Shallowing of water bodies

Water resources are decreasing

Source: https://lh5.googleusercontent.com/p/AF1QipPE_dgHQOHuFCTb1hoDe3ShG_z8qZ24TpPUPSQf=h1440.

The air temperature rises dramatically (Figure 1). Annual air temperatures increased by 0.28°C every 10 years for the whole country (Salnikov et al. 2015). Temperatures in Kazakhstan are projected to rise at a faster rate than the global average, with potential warming up to 5.3°C by the 2090s (World Bank 2021b). These changes are likely to threaten human lives, livelihoods, and ecosystems.

Increasing landslides, mudflows, and floods (Figure 2). The melting of glaciers may lead to glacial lake outburst floods.[20] The increased runoff will raise the risk of mudslides and flooding. The glaciers on the northern slopes of the Trans-Ili Alatau have shrunk by 40 percent in 53 years, at an average annual rate of 0.76 percent (Vilesov 2015). Dense urban development along rivers and the absence of protective green buffers expose the city to risks of flooding which can cause huge economic and social damage.

The number of extreme weather events grows (Figure 3). Projections by 2050 indicate an increase in annual average precipitation by 0.8–15.0 percent. The greatest amount of precipitation is expected in winter months. So, there will be more droughts during summertime from July till September.[21] It will lead to land degradation and desertification and will affect global food security as the nation represents one of the world's largest exporters of food.

Water resources are decreasing (Figure 4). Despite the flood threat, it is important to remember that increased river flow through the middle of the twenty-first century will be followed by a longer-term decline flow (World Bank 2021b). A continued decrease in the stable glacial runoff can endanger urban water resources, including irrigation resources, due to a decrease in precipitation in hot seasons, which leads to droughts.

Addressing these climate-related problems requires a comprehensive approach based on enhancing green infrastructure that aims to preserve and restore green spaces, which can help with the loss of biodiversity and adaptation to climate change to protect vulnerable populations and infrastructure.

1.2. Overview of Proposed Green Network for Almaty Agglomeration

The vision of the Green Network for Almaty Agglomeration (Figure 6) is an ambitious initiative that aims to establish a network of interconnected continuous green corridors along Almaty's major rivers, road buffers, and recreational routes from the foothills to the Kapchagai Reservoir. This involves both expanding forest cover and ensuring it forms a cohesive network, linking various landscapes within it, including urban parks, foothill forests, meadows, and riparian forests. Green pedestrian, bicycle, and touristic routes, incorporated into the green network, will offer an immersive experience, allowing residents and visitors to appreciate the diverse cultural and natural landscapes of Almaty Agglomeration while enjoying the fresh air and tranquility.

The study revealed[22] that the main green corridors forming the ecological basis of the Green Network run alongside six major rivers of Almaty: Malaya Almatinka, Esentai, Bolshaya Almatinka, Boralday, Kargalinka, and the Big Almaty Channel named after Kunayev. Corridors, that form the roads' green buffers, small river tributaries, and boulevards in cities, complement and support main corridors within the network.

[20] NASA Earth Observatory. 2015. Glacier Lake Outburst Flood near Almaty https://earthobservatory.nasa.gov/images/86300/%20glacier-lake-outburst-flood-near-almaty.

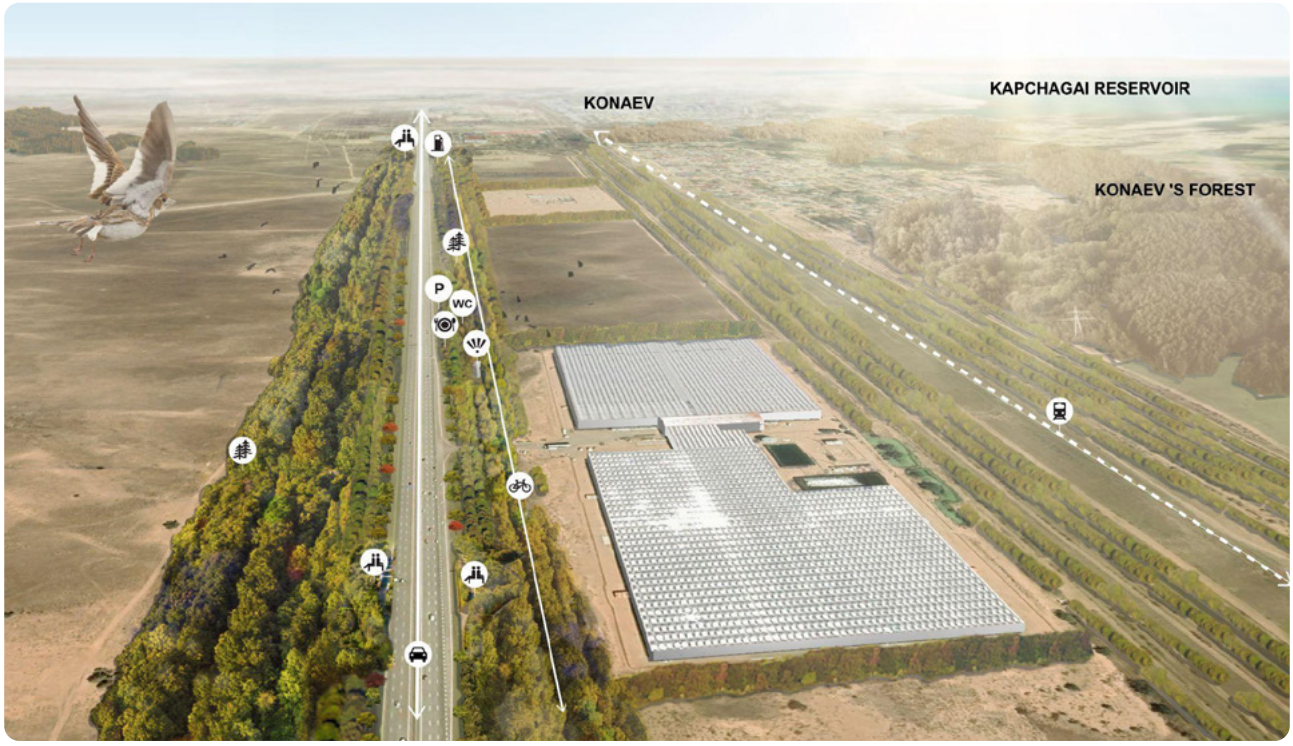
[21] For an overview of the Climate Risk Profile: Kazakhstan, see the 'Climatelinks' website. Article June 16, 2017 https://www.climatelinks.org/resources/climate-risk-profile-kazakhstan.

[22] Refer to Annex 1, section 1.3 for more information on analytical assessments for Almaty Agglomeration.

The proposed Green Network will not only help address climate challenges but also can support biodiversity, meet recreational needs of the citizens, promote tourism, and foster a thriving environment for local businesses to flourish.

The first pilot project within the proposed Green Network is the Greenway to Konaev Action Plan (GKAP), spearheaded by Akimat of Almaty Oblast (Figure 5). The project aims to establish a continuous green corridor of diverse protective greenery accompanied by recreational and tourist infrastructure along the Almaty-Konaev highway leading to the Kapchagai Reservoir. After implementation of the project, the environmental connectivity and tree canopy of the area will increase; air quality will improve; the space along the highway itself will be protected from wind, snow, and sand; and attractive landscaping will allow motorists and cyclists to appreciate the diversity of the region's natural landscapes.

Figure 5. Visualization of 'The Greenway to Konaev' green corridor



Source: MLA+.

1.3. Green Network Key Principles

Green networks are made up of various elements—for example, parks, woods, open areas, and river buffers—sometimes known as green infrastructure.[23] "Green infrastructure is **a strategically planned network of natural and semi-natural areas** with other environmental features, designed and managed to deliver a wide range of ecosystem services, while also enhancing biodiversity. Such services include, for example, water purification, improving air quality, providing space for recreation, as well as helping with climate mitigation and adaptation. This network of green (land) and blue (water) spaces improves the quality of the environment, the condition and connectivity of natural areas, as well as improving citizens' health and quality of life" (European Commission[24]). Each green infrastructure element is valuable and is part of a greater green network of an area.

[23] NatureScot (Scotland's Nature Agency) - *Green network definition:* Green networks | NatureScot.

[24] For a general overview, policy, studies, and publication, see the European Commission website: Green infrastructure - European Commission

Figure 6. The proposed vision of Green Network for Almaty Agglomeration

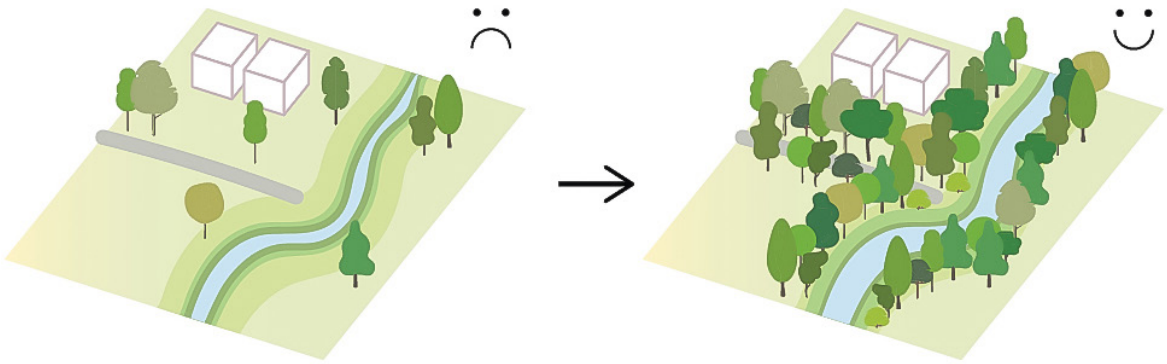
Source: MLA+.

A green network takes the form of ecological cores and interconnected green corridors (Figure 7) following landscape ecology principles (Dramstad, Olson, and Forman 1996).

Cores represent large, least fragmented green areas including city parks, forested foothill areas, and wide green valleys in the steppe and desert zones (Dramstad, Olson, and Forman 1996). These core areas function as important ecological hubs and recreational spaces.

Green corridors are linear links of vegetation strips (Dramstad, Olson, and Forman 1996), serving as ecological connections between habitats (cores) while also facilitating cycling and walking paths, as well as recreational spots. Green corridors typically include rivers' valleys, canals, boulevards, road buffers, railway buffers, windbreaks, and linear parks.

Figure 7. Visualization of interconnected green corridors into network along a river and a road buffer



Source: MLA+.

These are the key principles of green networks for Almaty Agglomeration:

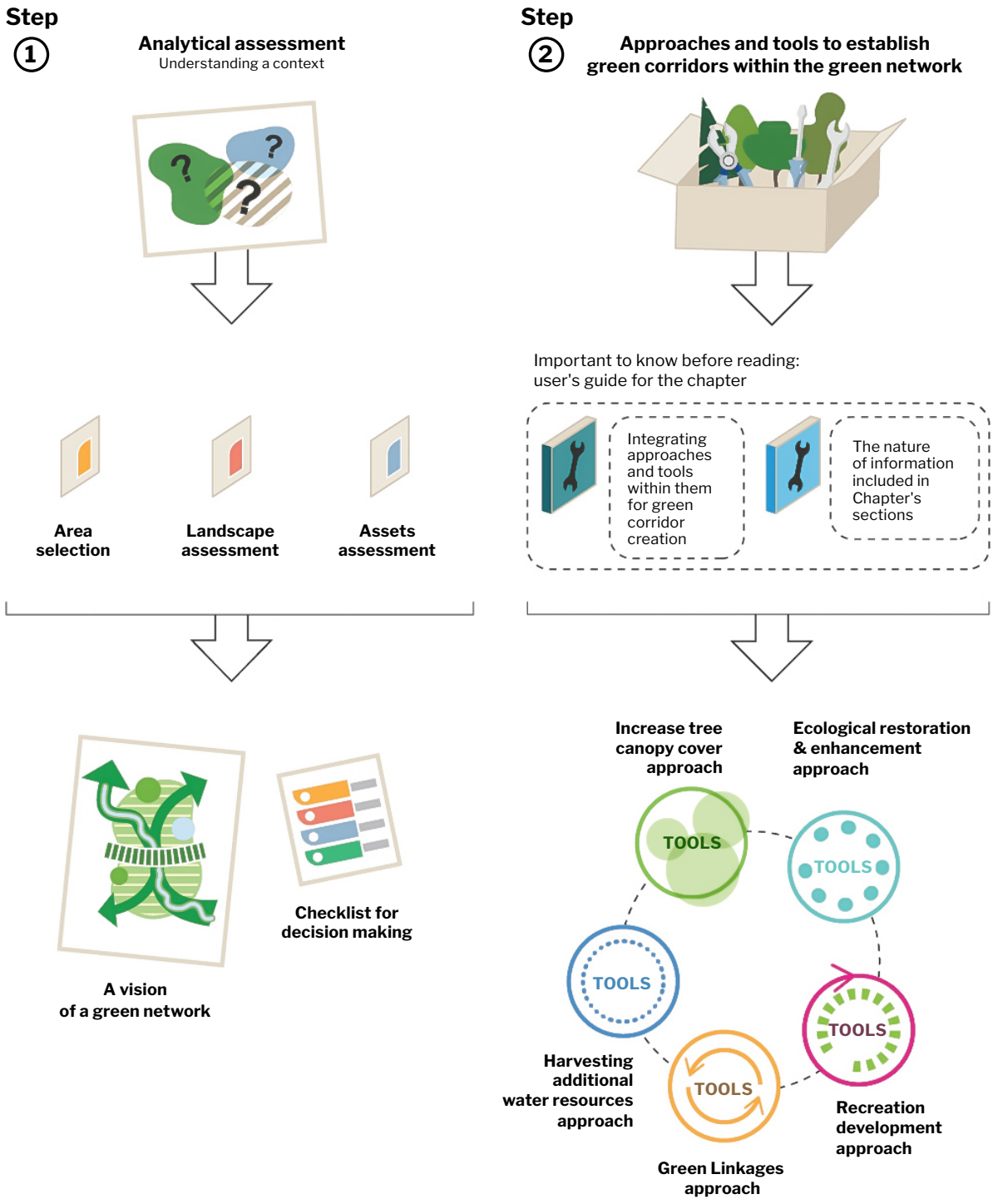
- **Preserve greenery first, create later.** Prioritize the protection and care of existing trees and shrubs, with new plantings as secondary measures.
- **Form a connected network.** Plant trees within connected green corridors, strategically aligning with major rivers as primary corridors. This ensures a sustainable and resilient ecological structure vital for biodiversity in Almaty Agglomeration's arid climate (IPBES 2018). Riparian areas act as biodiversity hotspots, playing a crucial role in soil protection, riverbank consolidation, and as habitats for lots of species. Overall connectivity not only allows movement of animals, birds, and insects but also helps people move comfortably around the city.
- **Ensure multifunctionality.** Each green infrastructure element provides functional diversity, combining ecological, sociocultural, and economic functions, and offers many ecosystem services. For instance, an embankment not only provides recreation spaces but also supports educational activities and enhances air quality, improves microclimate, and provides shade.
- **Cross-scale.** Design green infrastructure elements at various scales, from regional—network of green corridors—overseen by departments of Akimat of Almaty Oblast and Akimat of Almaty City, to local projects—such as parks, embankments, or street trees consolidated into corridors. Each green infrastructure element, whether at a large or small scale, contributes significantly to the broader green network.
- **Integrate** green infrastructure seamlessly with transportation and engineering systems.
- **Enable social engagement.** Involve stakeholders in planning and maintenance from the project's inception. Identify the owners of natural capital and primary beneficiaries of ecosystem services.
- **Prioritize accessibility.** Implement green infrastructure where there is the highest demand, ensuring accessibility for citizens.

The proposed vision for the green network for Almaty Agglomeration was established during the initial phase of the green corridor concept development, as illustrated in Figure 8. This first step, known as Analytical Assessments, encompasses the following analytical tasks: area selection for the green network, landscape assessment, and assets assessment.

In addition to vision creation, these assessments are preliminary steps to understand the context, challenges of the territory, project goals, and desired benefits. The information derived from these assessments helps in selecting appropriate approaches and tools.

For more information about the assessments, refer to Annex 1.

Figure 8. Steps to create a green corridor within a green network



1.4. The Benefits of Green Network Creation

Green corridors, as a part of a green network, will provide Almaty Agglomeration residents with a range of environmental, economic, and social benefits.[25]

- Reduction of disaster risk and increase in climate resilience against the impact of natural hazards in cities such as flooding, erosion, landslides, drought, and extreme heat
- Tree canopy expansion, air quality improvement, mitigation of heat island effects, and sequestration of more carbon
- Public health improvement through the development of bicycle and pedestrian routes, reduced reliance on automobiles, and expansion of urban green areas for public use
- Fostering local community cohesion by engaging various stakeholders in the project
- Elevation of local residents' well-being, economics, and real estate value through project participation, carbon certification, and attraction of tourists and customers to boost local tourism
- Local species and habitat preservation and enhancement and biodiversity restoration, thereby strengthening local landscape identity
- Water and food security, sustainable water resource management, reuse of water for irrigation, and improved water quality in rivers and groundwater infiltration.

1.5. Guidelines to Support the Design and Establishment of Green Corridors within the Green Network

Green Corridor Planner Guidelines, Almaty Agglomeration, Kazakhstan, were developed as a guidance document to support the growing demand for establishing green corridors and to connect them to a greater green network, urban regeneration through greening, and landscape regeneration through enhanced habitat connectivity.

This comprehensive guide, including analysis, recommendations, approaches, and tools, intends to support Akimat of Almaty and Akimat of Almaty Oblast in creating terms of reference, policies, and priorities for green corridor projects within a greater vision of establishing a green network throughout Almaty Agglomeration. These guidelines aim to support the G4 cities, urban landscape planners, ecologists, other professionals, and students in the design and creation of green corridors through inspiring green infrastructure project examples and case studies.

Chapter 2 describes approaches and tools to establish green corridors. This chapter outlines five approaches to address climate challenges and establish sustainable and diverse green corridors: increase in tree canopy cover, ecological restoration and enhancement, green linkages, recreational development, and harvesting of additional water resources. Tools, serving as design solutions, are grouped by these approaches and examples from Almaty Agglomeration are provided. First, choose the approach(es) most needed for the situation and then select appropriate tools.

The user guide at the beginning of the chapter explains how to use the information provided in the sections and how it is organized.

[25] For a general overview of co-benefits of nature-based solutions in urban areas, see the full catalogue by the World Bank Group (World Bank 2021a).

1.6. Checklist for Decision-Making

The following checklist aims to gather essential information for using the approaches and tools for green corridor creation in this guideline. This information assists the user in seamlessly transitioning to the practical application of Chapter 2.

- Determine an area of consideration with stakeholders and a landscape specialist; understand your scale (refer to Annex 1, Section 1.1).
- Conduct landscape assessment: determine landscape zones (refer to Annex 1, Section 1.2).
- Conduct assets assessment and prioritize elements for a green corridor (refer to Annex 1, Section 1.3).
- Define the specific challenges a territory is facing.
- Create a vision of a green corridor system (refer to Annex 1, Section 1.2) and discuss it with all stakeholders.
- Write or define your desired green corridor objectives.
- Define the potential benefits for green corridor creation.

2. Approaches and Tools for Creating Green Corridors

2.1. User's Guide for the Chapter

The user's guide for Chapter 2 consists of two sections: *integrating approaches and tools for green corridor creation*, which explains how to select appropriate approaches and the tools for your project, and *the nature of information included in the sections*, which guides the reader through the different subsections and information provided to take the next step in establishing green corridors.

2.1.1. Integrating Approaches and Tools for Green Corridor Creation

There are five approaches that group 24 tools. Therefore, users can select suitable approach(es) for their project.

Users can choose all five approaches simultaneously in one project—this will make a green corridor the most sustainable and multifunctional system—or select just one approach that is the most suitable for the context.

Critical considerations enable the **selection of approach(es)** for green corridors. This section describes three important principles for the selection: **assess objectives, challenges, and benefits of each approach** (Figure 9). Decision regarding an appropriate approach can be made based on the outcomes of analytical assessments, which are described in Annex 1.

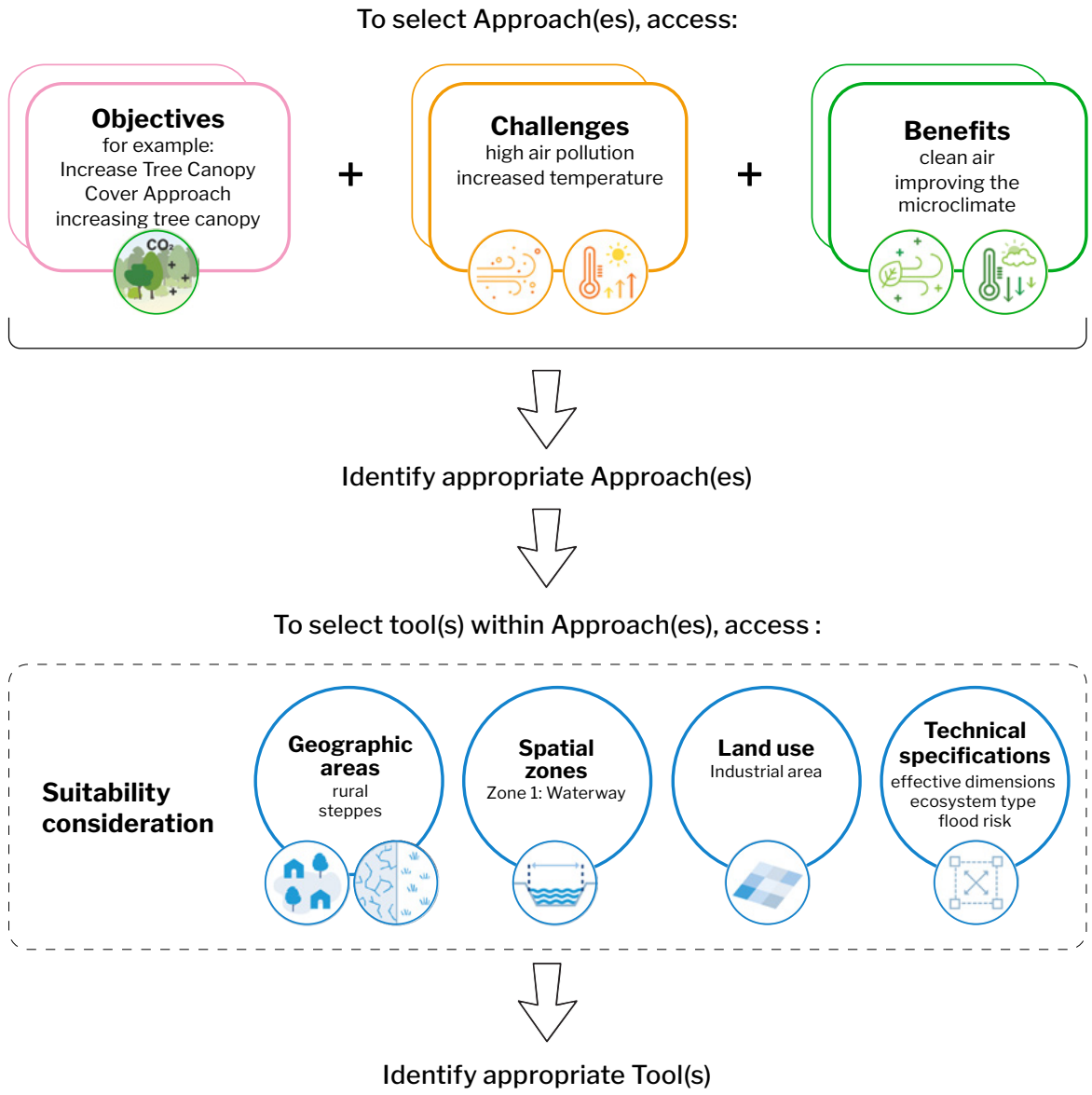
Each approach is characterized by an objective, which can help a user understand what quality will be added to a green corridor. For example, *the Ecological Restoration and Enhancement Approach* aims to protect and restore biodiversity; using this approach, the green corridor becomes more resilient.

In each approach, challenges and benefits are also provided, which can help a user understand the challenges this approach can address and its benefits. For example, the *Increased Tree Canopy Cover Approach* can mitigate air pollution and increased temperature challenges and bring the benefits of clean air, comfortable microclimate, and shade from the tree cover.

Each approach has tools, which serve as design solutions to establish a green corridor. **To select tools** appropriate for a particular context, a user may access the **suitability consideration** (Figure 9) for each tool. The description of each tool can help a user understand its purpose.

Suitability consideration of tools can help in understanding whether a tool is suitable for a particular location. This may, for example, depend on available space, specific land use, or environments. These considerations are included in a tool's description under the geographic, spatial, land use, and technical specifications.

Figure 9. Information on each approach and its tools is organized to provide an understanding of effective integration into a context



Note: The lists in the boxes are examples and not intended to be exhaustive.
Source: MLA+.

2.1.2. The Nature of Information Included in Each Section

The chapter *Approaches and Tools for Creating Green Corridors* explains how all approaches work together and how they provide resilience and diversity. Chapter 2 has five subchapters, one for each approach.

Each subchapter includes the following elements:

- **The description** page with the following sections: *objective, challenges, benefits,* and *illustration of tools grouped by approach;*
- **Tools' characterization,** which includes: *description, co-benefits, what? how? where? suitability consideration,* and *visualization of the tool.*

Description

Objective defines an aim of the approach, its slogan, and a visualization that describe a feature of the approach (Figure 10).

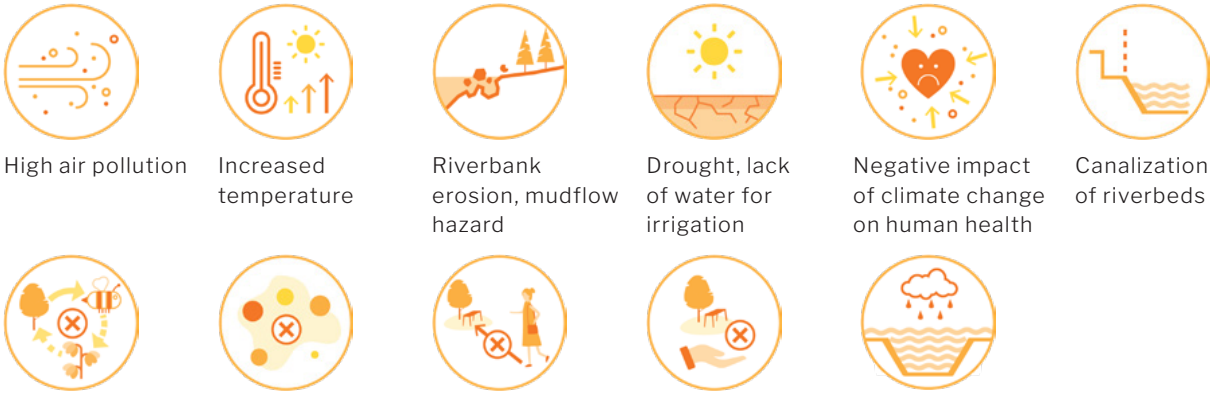
Figure 10. Approaches to Creating Green Corridors

Increase Tree Canopy Cover Approach | Ecological Restoration and Enhancement Approach | Green Linkages Approach | Recreation Development Approach | Harvesting of Additional Water Resources Approach

Source: MLA+.

Challenges represent the problems which could be faced with an approach (Figure 11).

Figure 11. Challenges that could be mitigated by all approaches



High air pollution | Increased temperature | Riverbank erosion, mudflow hazard | Drought, lack of water for irrigation | Negative impact of climate change on human health | Canalization of riverbeds

Loss of natural ecosystems and biodiversity | Habitat fragmentation | Lack of accessibility of parks and nature | Lack of infrastructure for recreation | Flooding

Source: MLA+.

Benefits outline the advantages of an approach (Figure 12).

Figure 12. Benefits related to approaches

Providing citizens with clean air | Improving the microclimate in the city | Tree canopy shade | Mitigation of flooding risks | Improving the health of the population | Biodiversity

Habitat connectivity | Tourist attractiveness | Accessibility of parks and nature | High-quality environment for recreation | Water for irrigation | Water saving and budget

Source: MLA+.

Illustration of tools grouped by each approach offers users an initial understanding of the application.

Tools' characterization

Description — *a brief explanation* of what the tool focuses on and its definition. It also includes a *reference picture* of an outcome of the tool or good existing example and *ecosystem-based practices* (Cohen-Shacham et al. 2019) (Figure 13), which are used to prioritize and understand how the tool works.

Figure 13. Ecosystem-based practices in the tool's description

Source: Illustration of MLA+ based on Cohen-Shacham et al. (2019).

Co-benefits — explains additional advantages a tool provides as part of the benefits of a common approach. For example, in the *Increased Tree Canopy Cover Approach*, all tools provide increased tree canopy and therefore *clean fresh air*. However, tools with agroforestry practices — for instance, the *Alley Cropping Tool* — provide co-benefits such as food production.

What? How? — This section provides technical details about a tool and specific recommendations, including step-by-step instructions to design and implement the tool.

Where? Suitability consideration — This section helps understand whether a tool is suitable at a location for green corridor creation.

Suitability considerations are divided into four categories (Figure 14–19):

1. **Geographic areas** determine suitable geography for a tool (Figure 14).

To determine the landscape zone, refer to Annex 1, section 1.2 *Understanding the Landscape*.

Figure 14. Geographic areas icons

Urban	Rural	River valley	Mountain meadows and forests	Deserts and steppes
Urban environment, high population density	Low population density, agricultural areas, industrial and natural areas	Landscape zone in a depression made by the river, mostly represented by riparian willow forests	Landscape zone with forest, subalpine, and alpine meadow vegetation	Landscape zone north of Almaty, suitable for drought- and salt-tolerant plants

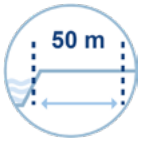
Source: MLA+.

2. **Spatial zones** have special physical characteristics of the landscape section in which a tool is used. (Figure 15).

Figure 15. Spatial zones icons

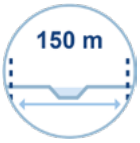
Zone 1: Waterway

Zone 2.1: Natural riverbed buffer
50 m from the water edge (for determination, use Figure 16)

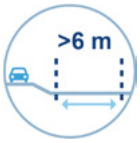


Zone 2.2: Concrete bank river buffer
50 m from the water edge (for determination, use Figure 16)

Zone 3: Area between buffers
Between Zones 2.1, 2.2, 5.1, and 5.2
Between buffers of two rivers (2.1/2.2) or two roads (5.1/5.2)
Between buffers of one river and one road (for example, 2.1, 5.1)



Zone 4: Two-sided concrete riverbed buffer
75 m on the concrete riverbed axis, 150 m in total

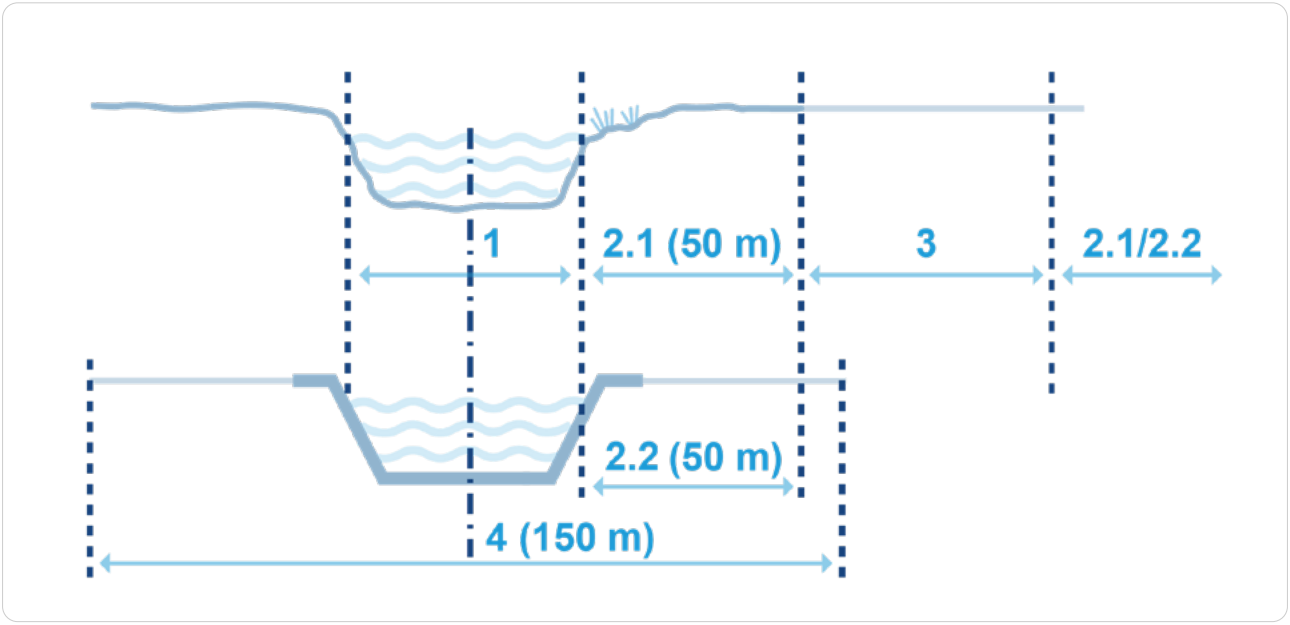


Zone 5.1: Road buffer_Highway
More than 6 m from the roadside
(Figure 17)

Zone 5.2: Road buffer_Street
Minimum pavement opening size - 1.5 m (absolute minimum 1.3 m)
Minimum planting strip is 2 m wide (Figure 17)

Source: MLA+.

Figure 16. Illustration of a common section for application of spatial Zones 2.1 and 2.2

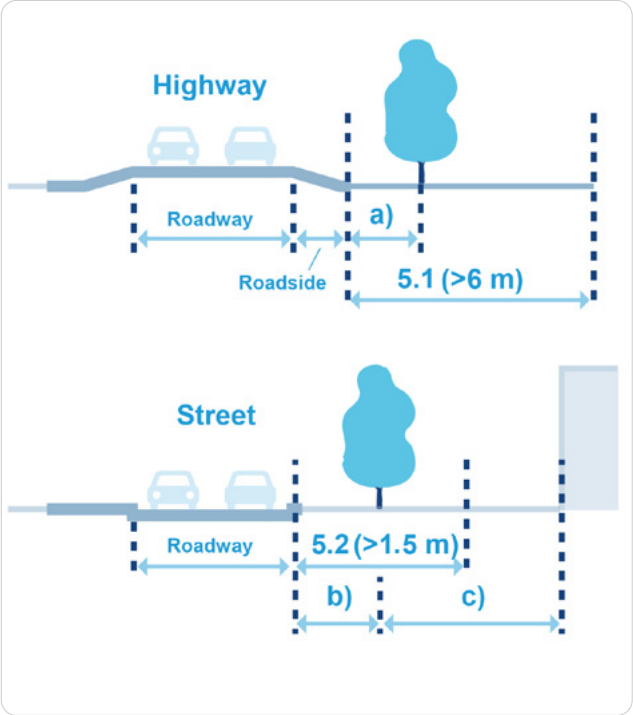


Source: MLA+.

Note: Zone 2.1 (upper illustration) has a natural riverbed; Zone 2.2 (bottom illustration) has a concrete riverbed.

Zone 5 refers to road buffers: a buffer from highways (5.1) and a buffer from streets (5.2) (Figure 17).

Figure 17. Illustration of a common section for application of spatial Zones 5.1 and 5.2



Source: MLA+.

5.1: Road buffer_Highway – more than 6 m (Bentrup 2008) (for effective noise protection - more than 20 m).

a. Distance from curb to tree trunk - 2 m[26]

5.2: Road buffer_Street – pavement opening - 1.5 m[27] (absolute minimum 1.3 m). The planting strip is minimum 2 m wide. The tree should be planted in the middle of the planting strip.

b. The minimum distance from the tree to the inner side of the curb is 0.65 m (1.3 / 2).

c. The minimum distance from the building façade to the tree is 3 m (Werkgroep Handboek Groen 2021).

Highways are outbound roads from Almaty City to Almaty Oblast, with intensive truck and car traffic. The buffer starts from the edge of the road. The minimum width of the planting strip is 6 m. However, the width should be more than 20 m to provide noise protection.

The **streets** are located in an urban environment. Street trees (between curb and property line) could be planned if there is 7 m[28] between the facade and the curb. It is recommended to reduce the minimum parameters to 3.85 m.[29] Reducing minimum setbacks from facades and the curb is not intended to degrade tree life but to allow trees to be planted on narrower streets. Note that it is better to leave more uncompacted soil around the tree and more space for crown development. The optimal measurement of the planting strip will depend on the size of the trees and the available space.

According to the law,[30] the **minimum planting strip width along streets** is 2.7 m, which includes:

- 0.7 m from the tree to the pathway and
- 2 m from the tree to the edge of roadway

The distance from the facade to the tree is 5 m.

[26] Code of Rules of the Republic of Kazakhstan. 2013. CR RK 3.01-101-2013*. Urban Planning Layout and Development of Urban and Rural Communities: https://online.zakon.kz/Document/?doc_id=39214714.

[27] Code of Rules of the Republic of Kazakhstan. 2013. CR RK 3.01-101-2013*. Urban Planning Layout and Development of Urban and Rural Communities: https://online.zakon.kz/Document/?doc_id=39214714.

[28] The distance is conditioned by a minimum frontage setback of 5 m and a minimum curb setback of 2 m. For general overview, see Rules of maintenance and protection of green spaces of Almaty City. 2023. Decision of XXXII session of the Maslikhat of Almaty City of VII convocation dated January 17, 2023, № 211. Appendix 2: https://adilet.zan.kz/rus/docs/V23R0001710.

[29] The distance is conditioned by a minimum frontage setback of 3 m and a minimum curb setback of 0.85 m (1.3 m / 2 + 0.2 m).

[30] For general overview, see Rules of maintenance and protection of green spaces of Almaty City. 2023.

The following are the **recommended parameters** to allow for planting of trees in more constrained conditions:

- paving band along a curb – 0.8 m wide (DTAH et al. 2013).
- pavement opening minimum width – 1.5 m (DTAH et al. 2013) (absolute minimum 1.3 m); planting strip minimum width – 2 m; the tree should be planted in the middle of the planting strip.
- minimum distance from the tree to the inner side of the curb is 0.65 m (1.3 / 2).
- minimum distance from the facade to the tree is 3 m (Werkgroep Handboek Groen 2021).
- optimum width of the planting strip and pavement opening depends on the expected trunk diameter at maturity (see Table 2).

Figure 18. Land use icon

Source: MLA+.

3. **Land use** refers to various land use types in spatial documentation; for instance, a tool could be suitable for industrial area land use type or in a sanitary protection zone (Figure 18).

Figure 19. Technical specifications icon

Source: MLA+.

4. **Technical specifications** refer to a variety of considerations, such as effective dimensions, anthropogenic load, ecosystem type, flood risk (Figure 19).

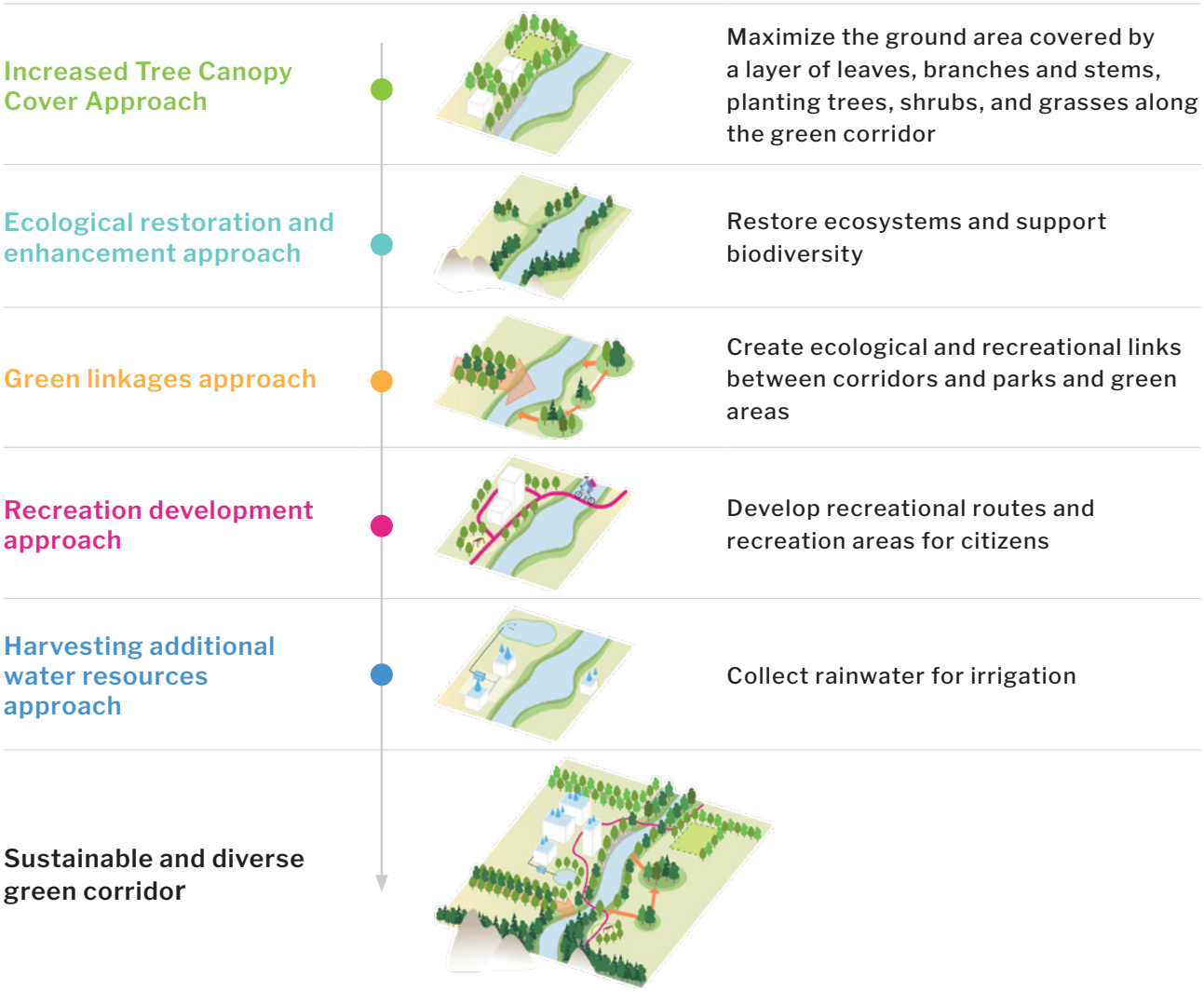
2.2. Illustration of Approaches and Recommendations

In the below sections of this chapter, the application of the tools for establishing Green Corridors in Almaty Agglomeration is visually represented. It comprises two bird's-eye view illustrations, depicting the 'before' and 'after' perspectives. In some cases, additional sections of the territory are provided to highlight important elements of the plan.

The locations for these visualizations were selected through extensive discussions with various stakeholders, including Almaty experts and local activists; pilot locations might serve as a starting point in discussions for future projects. For users' convenience, links to Google Maps are provided for each location.

This section outlines five approaches (Figure 20) grouping 24 tools to establish a quality — sustainable, diverse, recreational — green corridor. First, you choose the approach(es) most appropriate for the situation and then you select appropriate tools. You can choose all five approaches simultaneously in one project — this will make a green corridor the most sustainable and multifunctional system — or select just one approach which is most suitable for your context.

Figure 20. Illustration of approaches



Source: MLA+.

Table 1 provides a comprehensive summary of various approaches to establish green corridors, highlighting their main characteristics. These characteristics include the specific challenges that each approach addresses, the primary objectives they aim to achieve, the benefits they offer, and the appropriate tools that can be utilized to implement them. This table serves as a concise reference for understanding the different strategies and their implications. For a more detailed explanation and in-depth analysis of each approach, please refer to the full description provided in the next section.

Table 1. Approaches' summary table

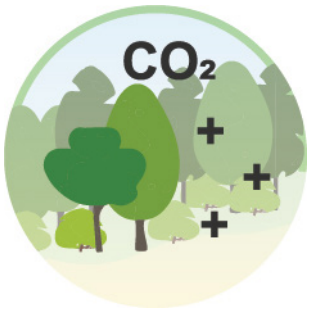
Approach	Challenges Addressed	Objective	Benefits	Tools
This column lists the title of each approach.	*This column will specify the challenges that an approach aims at.*	*In this column the specific goals of each approach are briefly described. It outlines the intended outcomes or results the approach intends to achieve.*	*In this column, the positive impacts and advantages of implementing each approach are outlined.*	*This column lists the various tools that can be used to implement each approach. The full descriptions of tools can be found in the next sections of chapter 2.*
Increased Tree Canopy Cover Approach	▪ High air pollution ▪ Increased temperature	Maximize the ground area covered by a layer of leaves, branches, and stems as well as plant shrubs and grasses along the green corridor, which will improve air quality and microclimate and provide shade in hot weather.	▪ Providing citizens with clean air ▪ Improving the microclimate in the city ▪ Tree canopy shade	Ⓐ Single tree planting Ⓑ Group tree and shrubs planting Ⓒ Riparian buffer Ⓓ Urban/peri-urban food forest Ⓔ Windbreaks Ⓕ Alley cropping Ⓖ Silvopasture
Ecological Restoration and Enhancement Approach	▪ Canalization of riverbeds ▪ Riverbank erosion, mudflow hazard ▪ Loss of natural ecosystems	Restore oppressed habitats as sustainable natural ecosystems and enhance local biodiversity in a city or beyond.	▪ Mitigation of flooding risks ▪ Habitat connectivity ▪ Biodiversity	Ⓗ Riparian forest conservation and/or restoration Ⓘ Foothills reforestation Ⓙ Full river restoration Ⓚ Single riverbank restoration Ⓛ Artificial watercourse landscape enhancement Ⓜ River daylighting Ⓝ Aquatic biotopes Ⓞ Terrestrial biotopes

Approach	Challenges Addressed	Objective	Benefits	Tools
Green linkages approach	▪ Habitat fragmentation ▪ Lack of accessibility of parks and nature ▪ Loss of biodiversity	Create ecological and recreational connections between green corridors and urban natural areas which makes it possible to reduce the fragmentation of the city's green network and create recreational links between parks and boulevards, so that any citizen can leave home and go for a walk in the shade of trees	▪ Habitat connectivity; ▪ Accessibility of parks and nature	(P) City boulevards (Q) Stepping stones
Recreational development approach	▪ Lack of infrastructure for recreation ▪ Lack of accessibility of parks and nature ▪ Negative impact of climate change on human health	Create continuous recreational paths in the shade of trees and opportunities for comfortable nature recreation, including rest areas	▪ High-quality environment for recreation ▪ Tourist attractiveness ▪ Improving the health of the population	(S) Recreational route (T) Intersection of the route with a street (U) Water edge access (V) Rest areas along the recreational route
Harvesting additional water resources approach	▪ Draught, lack of water for irrigation ▪ Flooding	Harvest rainwater from roofs to store it and use for irrigation purposes, and in new landscaping projects	▪ Water for irrigation ▪ Saving fresh water, and budget ▪ Improving the microclimate in the city	(W) Closed rainwater harvesting system (X) Open reservoir for water storage

2.3. Increased Tree Canopy Cover Approach

Objective

Maximize the ground area covered by a layer of leaves, branches, and stems as well as plant shrubs and grasses along the green corridor, which will improve air quality and microclimate and provide shade in hot weather.



Slogans

"First and foremost, plant by the river!"; "Greener, Continuously, Wider"; "Expand the green corridor with gardens and forest strips, increasing the productivity of local agro-landscapes!"

Figure 21. Challenges mitigated by the Increased Tree Canopy Cover Approach

Challenges

High air pollution

Increased temperature

Source: MLA+.

Figure 22. Benefits of the Increased Tree Canopy Cover Approach

Benefits

Providing citizens with clean air

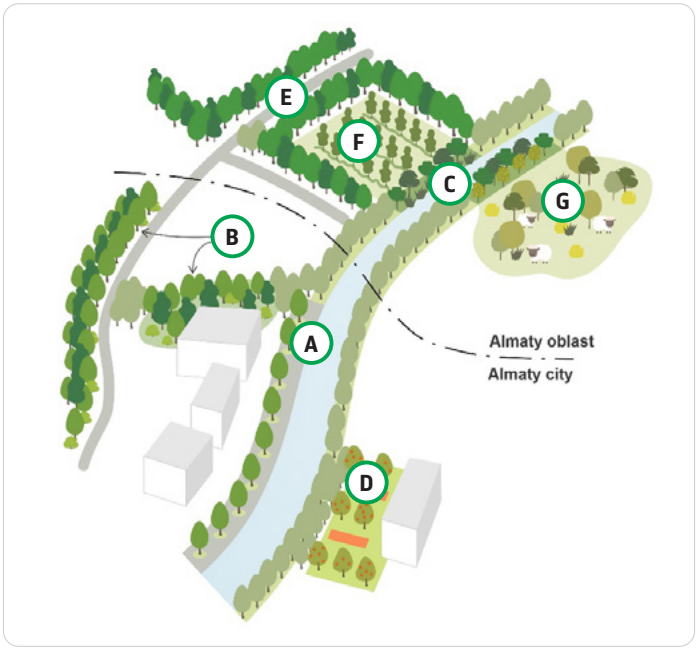
Improving the microclimate in the city

Tree canopy shade

Source: MLA+.

Illustration of tools for this approach

Figure 23. Tools for the Increased Tree Canopy Cover Approach



- **A** Single tree planting
- **B** Group tree and shrubs planting
- **C** Riparian buffer
- **D** Urban/peri-urban food forest
- **E** Windbreaks
- **F** Alley cropping
- **G** Silvopasture

Source: MLA+.

A Single Tree Planting

Description

This tool is focused on the creation of viewable and functional landscaping in constrained urban environments that require a high level of maintenance due to the expected high level of anthropogenic and man-made pressures. The tool describes the planting standards and planting site requirements. The *Single Tree Planting Tool* supports the *Increased Tree Canopy Cover Approach* (Figure 24).

Read more about planting and caring for urban trees in the Almaty City Tree Management Plan (TMP) (MLA+ 2023). The TMP is a roadmap that defines the goals and principles of tree and shrub plantation development in Almaty, as well as actions to achieve them. The plan is designed to help professionals actively and effectively manage the whole life cycle of trees and maximize the long-term benefits of green spaces created for city residents. The plan contains a recommended set of actions, a monitoring plan, recommendations for tree maintenance, plant assortment, and pest management.

Figure 24. An urban street in Canberra, Australia

Create
Planting of trees

Source: https://landezine.com/constitution-avenue-canberra-by-jane-irwin-landscape-architecture/.

Co-benefits

- Forming tree canopy in constrained urban environments
- Providing viewability and permeability of the area through a clear structure and lack of overgrowth
- Creating an attractive environment.

What? How?

- **Selecting species for planting.** Diversity of native plant species is a key principle for planting trees in urbanized environments, because when species diversity is increased, the overall health of urban green spaces increases. The species diversity rules for tree planting are summarized in Table 2.

Table 2. Species diversity rules for tree planting

Number of plants	Maximum percentage of trees of the same species
≤2	100
3–8	50
9–20	33
16–20	20
21–100[a]	10

Source: MLA+, based on Denver Parks and Recreation Department 18.08.2022. "Tree Care Rules & Regulations of the manager of the department of parks and recreation", City and County of Denver.

Note: When trees are planted in continuous rows, the species should change every two trees; deviations from the rules are possible with the approval of the appropriate executive agency (for example, in the case of a monoculture alley design).

a. For large projects involving the planting of more than 100 trees, the rule applies for each group of 10 trees.

The approved range of species for planting in Almaty City is listed in the TMP.

- **Requirements for saplings.** Selecting healthy saplings increases the survival rate of the planting. Saplings used for planting in urban environments should meet the following criteria:
  1. Minimum sapling trunk diameter of 3.8–5.1 cm (10/12 size class)[31] with a long trunk circumference of 12–16 cm (TeST 2022). Maximum trunk to crown ratio 1:1, in relation to a tree height of 250–300 cm.[32]
  2. Symmetrical crown cleared of dry and damaged branches (ISA 2021b).
  3. Straight, not bifurcated stems (exceptions may be those tree species in which multi-trunking is the norm) (ISA 2021b).
  4. Healthy, normally developed crown with a well-defined skeletal part (ISA 2021b).
  5. The sapling should be free of mechanical damage as well as signs of damage by pests and diseases.[33]
  6. Most trees should have only one leading shoot (the top should not bifurcate) (ISA 2021b).
- **Requirement for planting site and soil volume.** Under conditions of limited planting space, the minimum width of the planting site with unconsolidated soil must be observed (Table 3).

Table 3. Recommended minimum parameters of tree planting strips

1.	Expected trunk diameter at adulthood (cm)	10	20	30	40	50	60[d]	70	80	90	100[c]
2.	Required soil volume (m^3) for one tree (when planting more than two trees)	6 (6)	13 (8)	21 (14)	28 (18)	36 (24)	43 (28)	51 (34)	59 (40)	66 (44)	74 (50)
3.	Minimum width of the planting strip[a] (m)	2	2.1	2.2	2.3	2.5	2.6	2.7	2.8	3	3.1
4.	Minimum planting strip length at minimum width (m)[b]	3	6.5	9.5	12	14	16	19	21	22	24

Source: MLA+, based on Urban, J. 1992. *"Bringing Order to the Technical Dysfunction of Urban Forests."* J. Arbor. 18: 85–90.

Note:

a. The minimum planting width for single plantings is calculated from the expected adult trunk diameter (DBH) and root neck diameter (TFD) using the formula: TFD + 2 × 0.9 m. Where TFD = DBH × 1.3 (Hilbert et al. 2020), and 0.9 m is the minimum distance between the paving boundary and the expected adult trunk edge of the tree. For example, the optimum planting width for a petiole oak would be the following: DBH 180 cm × 1.3 + 1.8 m = 3.75 m.

b. Calculated for minimum soil volume (2), assuming a soil depth of 1 m.

c. An assumption is also made that by reaching a diameter of 100 cm, trees will be able to find root space on their own.

d. A soil volume of 40 m^3, open planting strip width of 2.5–3.0 m should be considered the recommended figure for most trees (Gemeente Amsterdam; Werkgroep Handboek Groen 2021, 72).

[31] Size class indicates circumference of stem in 1 m height (TeST 2022).

[32] Rules of maintenance and protection of green spaces of Almaty from 9.01. 2023. Registered by the Department of Justice of Almaty city on January 20, 2023 № 1710: https://adilet.zan.kz/rus/docs/V23R0001710.

[33] GKP "Almatyecologostroy". 2008. *Instruction on the creation of green spaces, technical supervision and monitoring of green spaces. Chapter II*, п. 4.2. Repealed by the decision of the Maslikhat of Almaty city dated 14.09.2018 № 260.

When trees are planted in grilles, the width of the tree trunk grille should be at least 1.5 m (ISA 2021a). The minimum distance from the tree trunk to the facade of the building should be equal to the radius of the potential crown of the tree in its mature state but not less than 3 m (Werkgroep Handboek Groen 2021).

If the street profile does not allow planting trees on sites with unconsolidated soil, special systems can be used. Soil compaction occurs during the construction of roads, parking lots, and pedestrian paths. This compaction makes the soil unsuitable for the healthy development of tree roots. However, there are specific methods that allow trees to take root such as

- pressure distribution systems,
- soil cells,
- sand or sift paving underlayment,
- reinforced concrete panels,
- stem grids, and
- root barriers (Gary et al. 2014).

- **Requirements for the design of the planting site**. The ground under trees must not be left bare, as this dries out the soil and creates a lot of dust. It is also forbidden to create a lawn, because when caring for it (namely mowing), there is a risk of damaging the tree root neck.

There are two options for soil treatment under trees in urban environments:

1. Plantings: ground cover plants, perennials, and shrubs with mulching of exposed soil areas. All these plantings should be no more than 90 cm high (ISA 2021c).

2. Mulching: The mulch shall be made of organic wood chips and/or permeable inorganic backfill. The finished surface after mulch application should be at least 2.5 cm below the surface of the adjacent sidewalk or curb (ISA 2021c).

- **The distance between trees** depends on their size and the presence of streetlights, overhead and underground utilities, and so on. Shade trees (Layer 1 and 2) should be planted at a distance of 10 m (DTAH et al. 2013) from each other if this corresponds to the provided soil volume and crown width at maturity. Ornamental trees (Layer 3) should be planted at a distance of 6 m (DTAH et al. 2013) if it corresponds to the provided soil volume and crown width at maturity. If the distance between trees is less than 6 m, the planting is considered as group planting.

- **Maintenance.** The Single Tree Planting Tool is predominantly designed for urban environments. Trees planted under this tool are less environmentally resilient than trees in group plantings. Therefore, they require more intensive care. The tool is applied in more confined conditions and therefore more conflicts with the urban environment may occur. To prevent these conflicts, regular maintenance, including risk management, pest control, and pruning, should be carried out.

Where? Suitability consideration

Geographic areas

Urban

Spatial zones

Zone 2.2: Concrete bank river buffer - Priority zone

Zone 3: Area between river buffers

Zone 5.2: Road buffer_Street

Zone 2.2 Zone 3 Zone 5.2

Land use

Public areas: squares, streets, pavements, embankments, parks, groves, boulevards, water bodies, beaches, and other facilities.

Note: The tool is recommended for use mainly in public areas, as it requires constant access for the maintenance of plantings.

Technical specifications

Dimensions: pavement opening minimum width - 1.5 m (DTAH et al. 2013) (absolute minimum 1.3 m); planting strip minimum width - 2 m.

Anthropogenic load: high anthropogenic and technogenic load, high share of impervious surfaces.

Territory visibility: areas where visibility of the landscape and/or unobstructed passage under or near a tree is required.

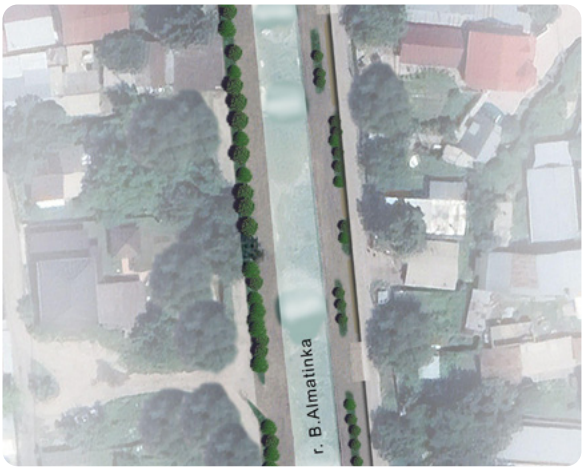
Visualization of the *Single Tree Planting Tool* in the Green Corridors context

Figure 25 and Figure 26 depict the planting of trees on the embankment of the Bolshaya Almatinka at the concreted places.

Figure 25. Single tree planting on the banks of Bolshaya Almatinka

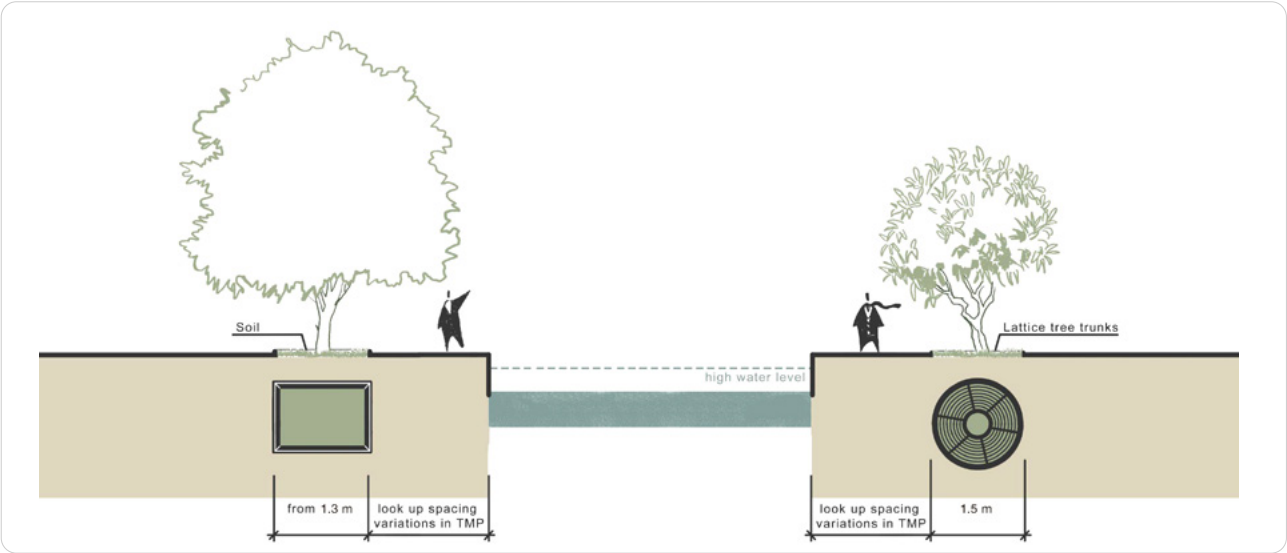
Before - concreted riverbed and tree planting of Bolshaya Almatinka river

After - improved vegetated riverbed of Bolshaya Almatinka river



Location: https://goo.gl/maps/WZMzBu1fGzwcM8it6.
Source: MLA+, Google images.

Figure 26. Visualization of single tree planting on the banks of Bolshaya Almatinka



Source: MLA+.

B Group Tree and Shrubs Planting

Description

This tool aims to create nature-like group plantings by planting trees and shrubs in locations with sufficient open space to form green corridors. The tool describes the standards for group planting and the requirements for the planting site. The tool supports the *Increased Tree Canopy Cover Approach* (Figure 27).

Read more about planting and caring for urban trees in the Almaty City TMP (MLA+ 2023).

Figure 27. A group of different sorts of trees in Berliner park

Create
Planting of trees, shrubs, and grasses

Source: Berlin, Park am Gleisdreieck - Flaschenhals, https://landezine.com/park-am-gleisdreieck-iii-flaschenhals-by-atelier-loidl/.

Co-benefits

- Increasing shading, reducing soil compaction, and decreasing moisture evaporation from the soil surface, reducing the impact of reflected heat per plant
- Attracting small urban animals, birds, and insects.

What? How?

- **Selection of species to plant.** Diversity of native plant species is a key principle for planting trees in urbanized environments. When species diversity is increased, the overall health of urban green spaces is enhanced.

Table 4. Species diversity rules for tree planting

Number of plants	Maximum percentage of trees of the same species
≤2	100
3–8	50
9–20	33
16–20	20
21–100[a]	10

Source: MLA+, based on Denver Parks and Recreation Department 18.08.2022. "Tree Care Rules & Regulations of the manager of the department of parks and recreation," City and County of Denver.

Note: When trees are planted in continuous rows, the species should change every two trees; deviations from the rules are possible with the approval of the appropriate executive agency (for example, in the case of a monoculture alley design).

a. For large projects involving the planting of more than 100 trees, the rule applies for each group of 10 trees.

The approved range of species for planting in Almaty City is listed in the TMP.

In group plantings, first and second layer trees are used. The crown should be permeable and allow sunlight to pass through. Group plantings also use shrubs of different sizes, ground cover, perennials, and annuals (in limited quantities, if necessary).

To vary the display through the year, the assortment should be selected such that the accent (foliage color, blossom, needles, shoot color) moves from plant to plant. This increases the decorative value of the group.

- **The species composition of the group** includes several species of trees and shrubs; the lower tier is filled with various grasses.
- **Requirements for saplings.** Selecting healthy saplings increases the survival rate of the planting. Saplings used for planting in urban environments should meet the following criteria:
  1. Minimum sapling trunk diameter of 2.5–3.2 cm (8/10 size class[34] with a long trunk circumference of 12–16 cm (TeST 2022). Maximum trunk to crown ratio 1:1, in relation to a height of 250–300 cm.[35]
  2. Symmetrical crown cleared of dry and damaged branches (ISA 2021b).
  3. Straight, not bifurcated stems (exceptions may be those tree species in which multi-trunking is the norm) (ISA 2021b).
  4. Healthy, normally developed crown with a well-defined skeletal part (ISA 2021b).
  5. The sapling should be free of mechanical damage as well as signs of damage by pests and diseases.[36]
  6. Most trees should have only one leading shoot (the top should not bifurcate) (ISA 2021b).
- **Spacing between trees and shrubs**
  - The minimum width of a strip for planting a group of only shrubs is 5 m (this refers to nature-like group planting). The height of such a group varies from 1 to 5 m (Werkgroep Handboek Groen 2021).
  - The minimum width of the strip for a group consisting of only trees, small shrubs, and grasses is 10 m. If possible, place two complete rows of trees (Werkgroep Handboek Groen 2021).
  - The minimum width of the strip for a group consisting of trees and shrubs is 10 m. The rule is that the width of the planting strip for shrubs should be more than half the height of the tree (Werkgroep Handboek Groen 2021).

[34] Size class indicates circumference of stem in 1 m height (TeST 2022).

[35] Rules of maintenance and protection of green spaces of Almaty City from 9.01 2023, Registered by the Department of Justice of Almaty City on January 20, 2023, № 1710 https://adilet.zan.kz/rus/docs/V23R0001710.

[36] GKP «Almatyecologostroy». 2008. Instruction on the creation of green spaces, technical supervision and monitoring of green spaces. Chapter II, п. 4.2. Repealed by the decision of the Maslikhat of Almaty City, dated 14.09.2018, № 260.

Where? Suitability consideration

Geographic areas

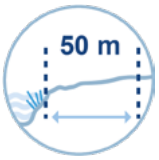
Urban

Spatial zones

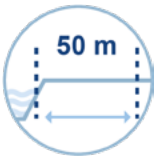
Zone 2.1: Natural riverbed buffer - Priority zone

Zone 2.2: Concrete bank river buffer - Priority zone

Zone 5.2: Road buffer_Street



Zone 2.1



Zone 2.2

Zone 5.2

Land use

Public areas: squares, streets, pavements, roadside lanes, roadsides, embankments, parks, groves, boulevards, water bodies, beaches, and other facilities. It can also be an undeveloped area that can be greened up.

Note: The tool is recommended to be used primarily in public spaces, as access to plantings and constant maintenance is required.

Technical specifications

Dimensions: large space for a planting area, a continuous area of open ground at least 9 m long and 6 m wide where two or more trees can be planted (Werkgroep Handboek Groen 2021).

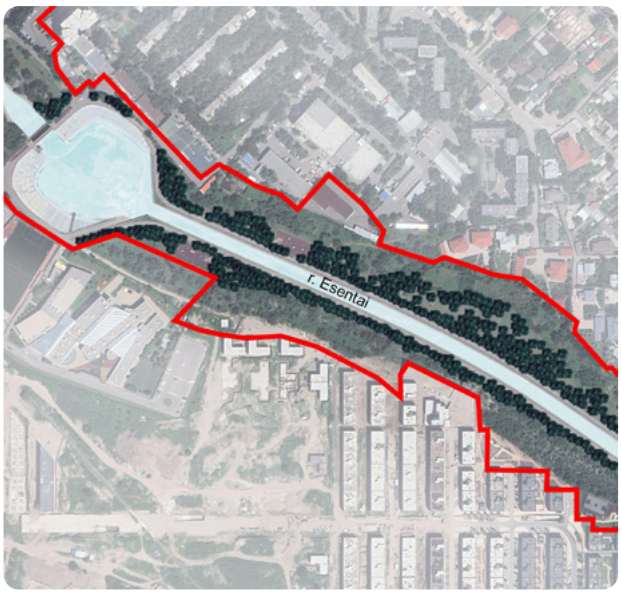
Visualization of the *Group Tree and Shrubs Planting Tool* in the Green Corridors context

Figure 28 and Figure 29 depict the planting of trees and shrubs in the Esentai valley in the undeveloped area between Al-Farabi Avenue and Zataevich Street.

Figure 28. Group tree and shrubs planting in the Esentai valley

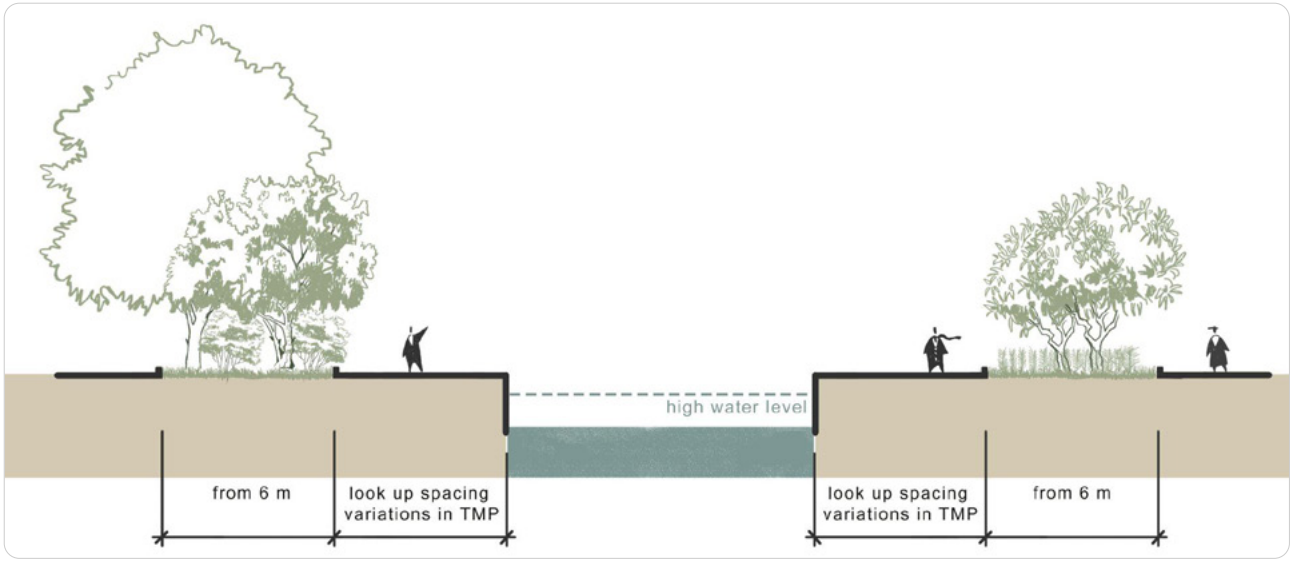
Before - Esentai valley

After - Green Esentai valley



Location: https://goo.gl/maps/FqQAAsXGwhyQh2mW6.
Source: MLA+ graphics, Google images.

Figure 29. Visualization of group tree and shrubs planting in the Esentai valley



Source: MLA+.

C Riparian Buffer

Description

This tool is the protective approach for all riverbanks that are adjacent to agricultural plots. It is focused on creation of multifunctional riparian buffers. A riparian buffer is an area adjacent to a stream that contains a combination of trees, shrubs, and/or other perennial plants and is managed differently from the surrounding landscape, primarily to provide conservation benefits (MacFarland, Straight, and Dosskey 2019). 'Multifunctional' means that the buffer provides new production benefits that can help compensate for taking land out of production. For example, buffers can be planted with trees and shrubs that produce fruits, nuts, decorative florals, or other non-timber forest products (NTFPs) that can be sold. The *Riparian Buffer Tool* supports the *Increase Tree Canopy Cover Approach* (Figure 30).

Figure 30. A riparian forest buffer grows along a small creek in Pennsylvania, where it has been planted to help stabilize streambanks, stop upland nutrient pollution from entering the stream, and shade and cool the water

Protect
Create a protective barrier/zone between the river and agricultural plots

Rehabilitate, Restore, Enhance
Forest conservation in the floodplain

Create
Apply riparian-friendly agroforestry practices

Source: The Pennsylvania Department of Conservation and Natural Resources (DCNR).

Co-benefits[37]

- **Production suitable for harvesting** without disturbing soil and grass cover on the vulnerable and often legally protected waterbody banks
- **Non-fertilizer agroforestry** that protects the river from pollution
- **Continuation of current legislated agricultural land use but practically making it more riparian friendly,** so that local farmers can use restored riparian buffers without conflicts between the stakeholders
- **Ecological enhancement** by providing shade, shelter, and food for fish and other aquatic organisms; creation of the wildlife habitat and corridors for terrestrial organisms, improving aquatic and terrestrial habitats along waterways
- **Reduction in pollution** and nutrient surplus from crop fields to water bodies
- **Prevention of erosion** and bank stabilization
- **Protection from flood** by giving rivers the space
- **Space for recreation**

What? How?

- **Make sure your buffer has three vegetation belts:** (a) native riparian forest trees and shrubs zone (Tool H); (b) a space for agroforestry practices where non-native fruit and other non-timber products can be grown; and (c) native herbs that are a barrier between the buffer and the agricultural fields. The most effective riparian buffer has three vegetation zones (Figure 31) (Garret 2005).

  Widths of the belts will vary based on goals of the buffer (Fox et al. 2005). For bank stabilization, the belt can be quite narrow. The widest buffer is created for nutrient capture. The approximate minimum width for the second belt is 40 m and for the third is 10 m. (University of Missouri 2013).
- **The first belt is riparian forest** (see more about restoration and conservation of the native riparian ecosystems in Tool H. *Riparian Forest Conservation and/or Restoration*).
- **The second belt can also be on a floodplain if it is wide enough.** A wide floodplain can have a wide riparian forest belt so that the agroforestry will not disturb the river. For example, *Typha sp., Scirpus sp., Carex sp., and Phragmites sp.*, which can be used in adobe construction, grow mostly on floodplains. Ensure that the first belt is wide enough to reach its goals.
- **The second belt is productive agroforestry ecosystem** adjacent to the riverbank where the system is implemented and supported by landowners and tenants interested in benefiting from the non-fertilizer cultivation and production of niche fruit and nut and NTFPs and concomitant beekeeping products.

  Berry products (*Hippophae sp., Berberis sp., Rosa sp., Elaeagnus angustifolia, Cornus mas,* and so on) and NTFPs such as woody florals and wickers (*Salix sp., Prunus tenella, Tamarix sp., Córnus sp.*) can be used. For the production of wicker products and decorative elements, it is possible to also use nut and fruit bearing Corylus sp. and Lonicera sp. as well as grassy plants.

  For the tree layer, it is possible to plant some species and hybrids of poplar, Populus sp., with the intent of wood harvesting (without uprooting) for technical needs or to create recreational conditions for the development of tourism activities. For the latter, turanga trees (*Populus diversifolia and Torulus pruinosa*) can be used, which will contribute to their preservation.[38]

[37] For an overview of co-benefits of riparian forest buffers, see the USDA website: Riparian Forest Buffers.

[38] Species are specially selected for Almaty Agglomeration with expert opinion: N. E. Zverev, biodiversity specialist, Institute of Botany and Phytointroduction of Plants of Kazakhstan - Species selection for agroforestry systems; O. A. Romanova, agroforestry specialist, KGU, Species selection for AF systems vision and selection of agroforestry systems.

All the suggested species are also suitable for planting in riparian forests but we recommend only restoring the riparian forest with them and not replacing.

Buffer effectiveness is best maintained by keeping it healthy and growing vigorously. Over time, trees produce shade that causes a reduction in the density and vigor of neighboring grasses. Introducing a zone of shrubs between trees and grasses minimizes the impacts of competition for light on the growth and vigor of the grass belt.

- **The third belt is a filter strip of native herbs.** Wild herbaceous species or perennial shrubs attract pollinators, prevent soil erosion, and filter runoff.

Where? Suitability consideration

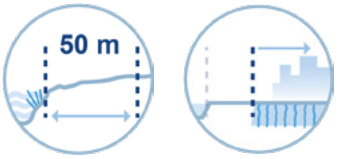
Geographic areas

Urban, rural

Spatial zones

Zone 2.1: Natural riverbed buffer
Additional requirement: The width of the first belt (riparian forest) is determined by the floodplain width. The widths of the second and third belts depend on the goals of the buffer. Floodplain, along with the river valley, should be marked out by the experts in river geomorphology and ecology.

Zone 3: Area between buffers
Additional requirement: Riparian buffers can be wider than 50 m (the width depends on the goals) and hit the area between buffers.



Zone 2.1 Zone 3

Land Use

Agricultural use: for agricultural production and farming.

The tool is used for areas between agricultural fields and the river bank.

Technical specifications

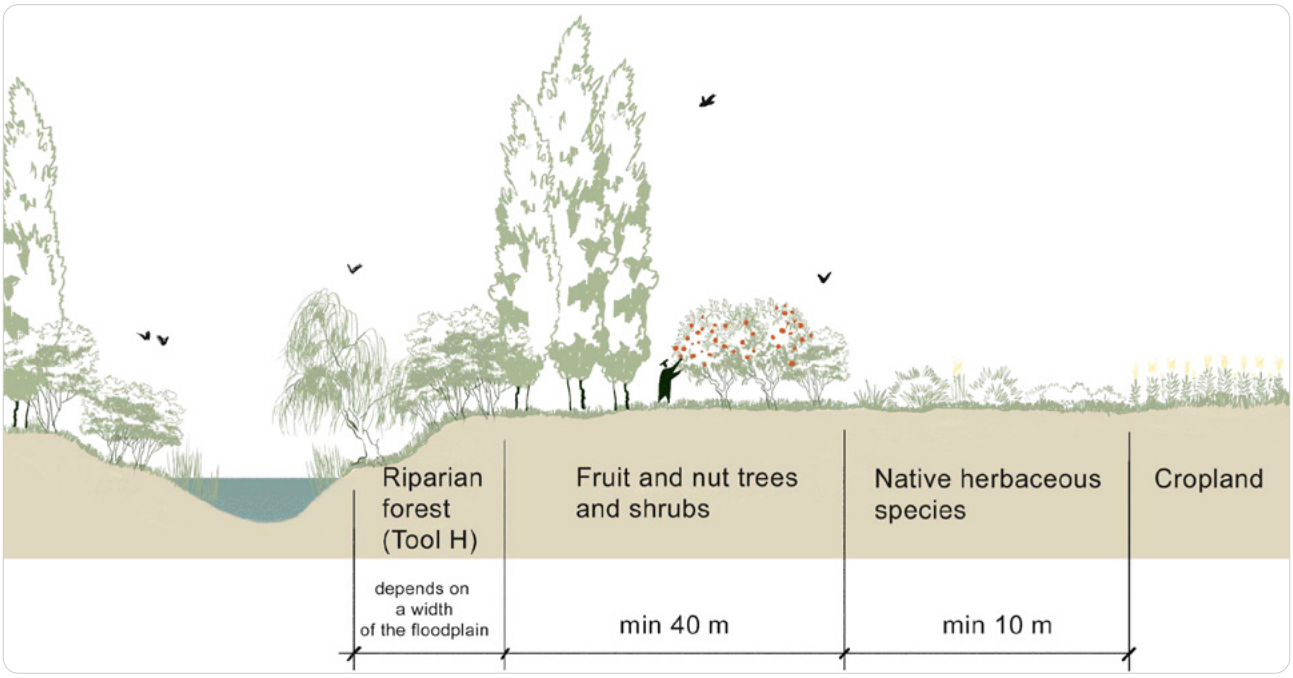
Food production safety: In urban areas, fruits can be grown only if the food safety and risk of accumulation of contaminants in them is researched.

Ecological safety: Agricultural products should be grown without the use of fertilizers.

Visualization of the Riparian Buffer Tool in the Green Corridors context

Three vegetation belts are depicted: riparian with native trees and shrubs of the floodplain forest (for example, willows, reeds), agroforestry belt with fruit and nut trees, and a belt with wild herbaceous species or perennial shrubs at the border with agricultural fields (Figure 31).

Figure 31. Riparian buffer vegetation belts



Source: MLA+.

D Urban/Peri-urban Food Forest

Description

This tool refers to the creation of perennial multicultural food production systems consisting of edible and non-edible plants, shrubs, and trees based on permaculture principles. These can be dacha[39] farms with perennial multilevel and multicultural woody plants, orchards where more than one type of plant is grown and produced, and urban gardens with fruit and berry plantations (Figure 32). The *Urban/Peri-urban Food Forest Tool* supports the *Increase Tree Canopy Cover Approach* and aims to increase the multifunctionality and biodiversity of the green corridor by providing agricultural opportunities for local farmers.

Figure 32. The urban food forest at Browns Mill in Atlanta, GA

Create
Planting of trees, shrubs, and grasses

Create
Food production

Source: https://www.aglanta.org/urban-food-forest-at-browns-mill-1.

[39] *Brockhaus Enzyklopädie* (in German). Vol. 26. Mannheim: F. A. Brockhaus. 1995.

Co-benefits

- **Sustainable food production** in the city by the citizens.
- **Increase in urban biodiversity** as fruit trees and shrubs are food for insects and birds (Romanova and Lovell 2021).
- **Uniting of the community around a common goal** — also for education in agroforestry and environmental sustainability. The local community, including school children, can participate in planning, designing, and organizing meetings and consultations; attending workshops on growing food crops; taking part in excursions; and gaining practical experience and knowledge on sustainable food production.
- **Support and promotion of dacha and garden agroforestry systems** instead of building up these areas with housing estates, townhouses, and cottages with a relatively small share of green spaces.

What? How?

- **Provision of plots for urban/peri-urban food forests by community members and/or local executive authorities** for planting nut, fruit, and berry woody species; forest species; and medicinal crops with the possibility of harvesting and public access. It is desirable that the plot is not fenced, and the food forest is provided irrigation and security.
- **Allocation of a plot of common land long-leased by a nongovernmental organization or limited liability partnership** that has a master plan/tree planting plan of the forest garden and provides the opportunity to join a club or association. Members commit to invest a certain number of hours in the care of the food forest in exchange for access to crops and the opportunity to visit the garden. Membership can also be provided as a paycheck to those involved in supporting the food forest.
- **Creation of a public project funded by a private company under environmental, social, and governance (ESG)** where people can see the benefits and contributions of the company to a practical cause, including the environment and food security.
- **Support for dacha owners who grow a variety of tree and shrub species on a larger area of their property** (for example, providing irrigation water), especially within the proposed green corridor.
- **Support for horticulturalists who grow more than one type of perennial** (for example, apples and hay and more complex systems).

Note: With the heavy pollution of Almaty, it is necessary to conduct research on the safety of food products obtained from public orchards. Studies show that tree species accumulate fewer heavy metals and polyaromatic hydrocarbons in their edible parts compared to annual plants and that careful washing of fruits helps get rid of most deposited contaminants. However, since risks do exist, research is needed (Romanova and Lovell 2021). In the case of increased health risks, it is recommended to focus on species edible for birds in urban systems to maintain biodiversity, whereas in the suburbs and Green Corridor of Almaty Agglomeration GCAA where crops are already grown, nut, fruit, and berry woody species are recommended.

Where? Suitability consideration

Geographic areas
Urban

Landscape zone
all landscape zones except river valleys and mountains

Spatial zones
Zone 3: Area between buffers

Zone 3

Land Use
Agricultural use: farming, horticulture
Public and business zones: land of universities, schools, and other public and educational organizations interested in development and education associated with agroforestry

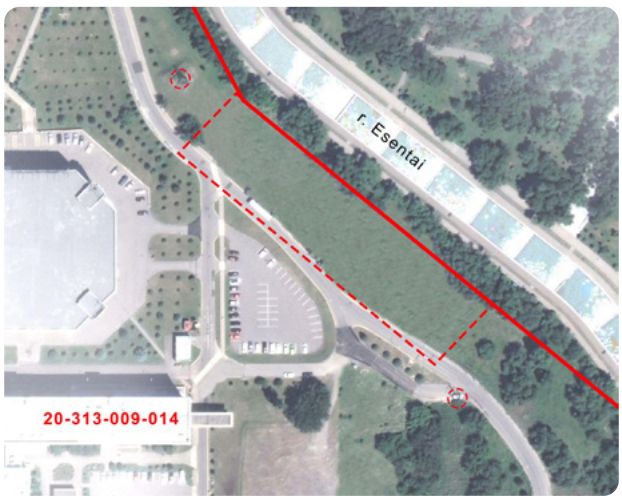
Technical specifications
Food production safety: Urban food forests should not be located near sanitary protection zones and industrial zones.

Visualization of the *Urban/Peri-urban Food Forest Tool* in the Green Corridors context

Figure 33 shows a public food forest near Esentai on the site of Kazakh National University instead of the parking lot.

Figure 33. A public food forest near Esentai

Before - the parking lot is located along the water



After - instead of a parking lot, a food forest is built and landscaped parking went deep into the plot

Location: https://goo.gl/maps/8hCyoH2mk7EyjQbL9.
Source: MLA+ graphics, Google images.

E Windbreaks

Description

This tool refers to the creation of linear plantings (Prokhorov 1973): 1–3 rows of trees and/or shrubs along fields, plots of land, or roads (Brang et al. 2001). Windbreaks refer to a number of techniques aimed at reducing wind speeds to protect plants, animals, or infrastructure in that area from adverse weather conditions such as high wind, snowstorm, hot wind (Gold and Garrett 2021) (Figure 34). The *Windbreaks Tool* supports the *Increase Tree Canopy Cover Approach*. The number of planting rows and width of the strips depend on the chosen windbreak design and climatic conditions.

Figure 34. Windbreaks in North Dakota

Protect
Protect plants, animals or infrastructure from adverse weather conditions such as high wind, snowstorm, hot wind

Create
Planting of trees, shrubs, and grasses

Source: World Atlas, Windbreaks and Shelterbelts: Wind Erosion Control In Farming https://www.worldatlas.com/articles/windbreaks-and-shelterbelts-wind-erosion-control-in-farming.html.

Co-benefits

- **Protecting plants and animals from the harmful effects of wind** such as shoaling, weatherization, desiccation, and hypothermia
- **Protecting transportation, industrial, and agricultural infrastructure** from the harmful effects of wind such as road icing and snow drifts; reducing energy costs for heating / cooling of buildings and other facilities
- **Protecting against anthropogenic wind-borne hazards:** pollution and odors from roads, industrial, and agricultural facilities
- **Improving soil quality** by reducing erosion, retaining the fertile layer, and increasing organic matter content.

What? How?[40]

- **Choose a suitable windbreak design.** Windbreaks affect wind speed, snow deposition, and soil moisture and are chosen depending on the specific objectives of the windbreak being planted:
    - ***Porous windbreak*** (gaps of more than 60 percent between trunks and up to 10 percent in crowns) is typically used in areas with cold snowy winters and high snowfall. The width of such strips is 5–15 m.

[40] Expert opinion: N. E. Zverev, biodiversity specialist, Institute of Botany and Phytointroduction of Plants of Kazakhstan, Species selection for agroforestry systems; O. A. Romanova, agroforestry specialist, KGU, Species selection for agroforesty systems and vision and selection of agroforestry systems.

- ***Moderately dense windbreak*** (gaps along the whole profile - 15–35 percent) is typically used in dry-steppe areas with irregular snow cover and dust storms, as well as on irrigated and drained lands. The width of such strips is 15–20 m.
- ***Dense windbreak*** is suitable for protection of livestock farms, residential buildings, roads, canals, and so on. It has a gap of not more than 10 percent along the longitudinal profile (Mesyats 1989).The width of such strips is more than 20 m.

- **Windbreaks should have a specific shape that helps minimize wind as much as possible** (Figure 35. Illustration of the principles of wind, sand, and snow protection). Trees and shrubs should be planted in several rows so that the cross-section of the planting looks like a triangle. In this way, the wind around the plants loses its strength and does not break the branches. For wind regulation, it is important to pay attention to the density of the crown, as trees with dense crowns and fragile branches can be broken by strong winds.

Figure 35. Illustration of the principles of wind, sand, and snow protection

Source: MLA+.

- **Select an assortment of plants.** The main protective function is performed by trees of the forest-forming species, which form the upper layer of plantation. Shrubs help protect the soil and contribute to snow accumulation. The optimal composition of trees and shrubs depends on the specific climatic conditions and functional task.

Assortment for the climatic zone of Almaty Green Corridors:

- **Tree layer:** Siberian elm *(Ulmus pumila)* 7–16 m, Lombardy poplar (*Populus italica f. Pyramidalis (DuRoi) Moench)* up to 20 m, hybrid 'Kazakh' poplar (*Populus hybrids* Kazahstans Bessch) up to 35 m. For the middle tier - field maple (*Acer campestre*) 8–15 m, Acer semenovii 5 m, Chinese elm (*Ulmus parvifolia*) 10–15 m.
- **Shrub layer:** caragana (*Caragana arborescens*) up to 4 m, *Berberis iliensis* up to 3 m.
- **To obtain additional products** (fruits, honey, medical products) in the windbreaks of agricultural fields, introduce bird cherry (*Prúnus pádus*), guelder-rose (*Vibúrnum ópulus*), and American persimmon (*Diospyros virginiana*). When planting windbreaks along high-traffic routes, fruit should be examined for safety for food consumption.

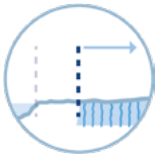
In the Green Corridors area, irrigation is needed for all species for the first 3–5 years and for 10 years during severe drought seasons. Most crops are sensitive to wind, including cereals (wheat, corn, barley), fruit crops (apples, pears, cherries, grapes), vegetables (cucumbers, tomatoes, peppers, eggplant), forage crops (meadow vegetation, Sudan grass), and flower crops (roses, gladioluses, and so on).[41] However, more research is needed to study the impact of windbreaks on the yield of crops grown in the region, including the risks of losing part of the crop due to shading.

[41] Expert opinion: N. E. Zverev, biodiversity specialist, Institute of Botany and Phytointroduction of Plants of Kazakhstan and O. A. Romanova, agroforestry specialist, KGU.

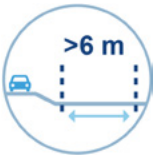
Where? Suitability consideration

Geographic areas
Rural

Spatial zones
Zone 3: Area between buffers
Zone 5.1: Road buffer_highway



Zone 3



Zone 5.1

Land Use
Agricultural use: for agricultural production and farming
Industrial area, road transport facilities, sanitary protection zones

Technical specifications
Dimensions: width from 5 m[42]

Visualization of the *Windbreaks* Tool in the Green Corridors context

Figure 36 shows the planting of windbreaks along the Almaty-Konaev highway and around industries on private plots to protect against pollution, noise, and odors as part of the pilot project GKAP.

Figure 36. Planting windbreaks along the Almaty-Konaev highway

Before - Almaty-Konaev highway unprotected from winds

After - Greenway to Kapchagai; forest belts along the route

Location: https://goo.gl/maps/jzzXp56ByRmnmuXp8.
Source: MLA+ graphics, Google images.

[42] Minimum width of the windbreak according to the windbreaks design described in the 'What? How?' section

F Alley Cropping

Description

This tool refers to the creation of rows of trees and shrubs planted in a specific order and at specific intervals, with cultivated plants growing between them (Gold and Garrett 2021) (Figure 37). Alley planting is an agroforestry practice that both increases tree canopy cover and provides an opportunity for local farmers to grow agricultural products. The *Alley Cropping Tool* supports the Increase *Tree Canopy Cover Approach*.

Figure 37. Planting between tree alleys

Create
Planting of trees, shrubs, and grasses

Create
Food production

Source: USDA, National Agroforestry Center, Alley cropping, https://www.fs.usda.gov/nac/practices/alley-cropping.php.

Co-benefits

- **Efficient land use.** Allows land to be used for growing food crops and trees or shrubs simultaneously, which promotes more efficient use of land resources and higher yields, as well as for reducing soil erosion and improving overall soil quality.[43]
- **Cultivation of valuable niche but long-growing products** with short- to medium-term profits from intercropped crops and alley fruits. For example, oak (*Quercus sp.*), walnut (*Juglans sp.*), chestnut (*Castanea sp.*) trees require a long time (50–100 years) to produce high-value wood. While they are growing, the crops grown in between the rows bring annual income. The medium-term income comes from the fruit trees (nuts, fruits) and more valuable crops that can be grown in the microclimate conditions created by young trees (medicinal herbs, vegetables, fruits, and berries) (Gold 2019).
- **Reduction in the need for nitrogen fertilizers** by using nitrogen-fixing plants in intercrops. In addition, they provide wind protection and create microclimatic conditions that allow a wider range of crops to be grown (Gold and Garrett 2021).

[43] Expert opinion: O. A. Romanova, agroforestry specialist, KGU.

What? How?[44]

- **Development of the alley system plan.** It should be developed based on soil types, irrigation capacity, groundwater table, and climatic regime of the particular area (field) and crops already grown by the tenant of the agricultural land. It will be more effective to continue growing already familiar crops for which there is equipment and knowledge and to introduce alley cultivation and test promising tree crops. As the trees grow, switch to new crops. For the first years, plant cereals and melons. When the trees grow older, transition to fodder crops (*Medica gosativa*), with young trees, and transition between the rows to berry shrubs (raspberries, currants, gooseberries). In a more closed canopy, select and transition to shade-resistant medicinal herbs or shade-resistant fodder crops.

  Under green corridor conditions, it is possible to use and study the following species for alley farming: Lombardy poplar (*Populus italica f. Pyramidalis (DuRoi) Moench*), hybrid 'Kazakh' poplar (*Populus hybrids Kazahstans Bessch*), white mulberry (*Morus alba*), red mulberry (*Morus rubra*), eastern American black walnut (*Juglans nigra*), Persian walnut (*Juglans regia*), blue spruce (*Picea pungens*), European spruce (*Picea abies*), ponderosa pine (*Pinus ponderosa*), Pallas pine (*Pinus pallasiana*), Scots pine (*Pinus silvestris*), Austrian pine (*Pinus nigra*), and hazel (*Corylus sp.*).

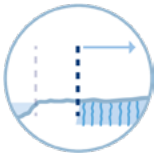
- **Changes in the legal framework** for wider application of this practice on irrigated agricultural land. Under current conditions, planting trees on agricultural land is allowed only with the intended purpose of 'perennial plantations', on reserve lands, and on lands designated for afforestation.

- **Creation of a planting management plan** to ensure sustainable existence of the tree population and to prevent major losses of biomass as a result of one-time felling. For leased land, it is necessary to work out the issue of timber/tree rights when the lease expires.

Where? Suitability consideration

Geographic areas
Rural
Landscape zone: deserts and meadows, steppes

Spatial zones
Zone 3: Area between buffers



Land Use
Agricultural use: The intended use of the land should allow for the planting of trees and/or shrubs.

Technical specifications
Food production safety: Alley cropping should not be near sanitary protection zones and industrial zones.

[44] Expert opinion: N. E. Zverev, biodiversity specialist, Institute of Botany and Phytointroduction of Plants of Kazakhstan, Species selection for agroforestry systems; O. A. Romanova, agroforestry specialist, KGU, Species selection for AF systems vision and selection of agroforestry systems.

Visualization of the *Alley Cropping Tool* in the Green Corridors context

Figure 38 shows the formation of fruit and nut alley plantings near Malaya Almatinka, with tree rows oriented from west to east. The distance between tree rows is determined by the size of the machinery used to harvest the crop (Figure 39).

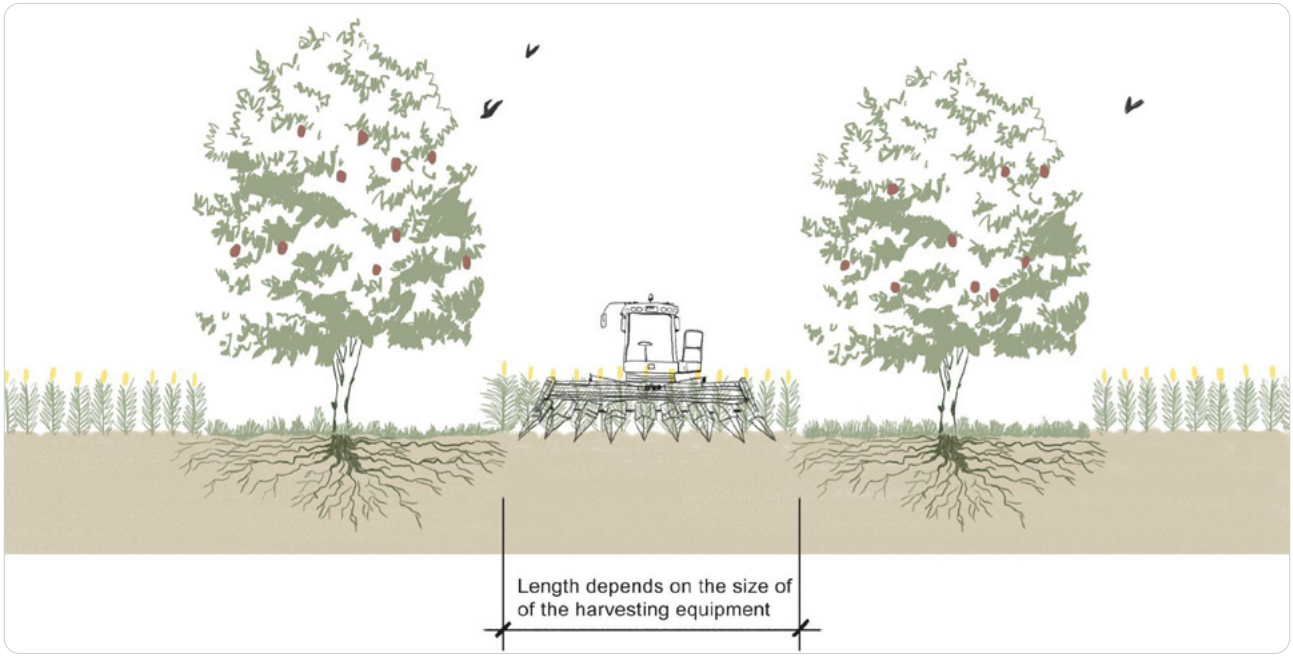
Figure 38. Alley plantings near Malaya Almatinka

Before - agricultural fields near Malaya Almatinka

After - alley farming; growing not only crops but also fruit and nut trees and trees with valuable timber

Location: https://goo.gl/maps/f5jvavSmH483KZSk6.
Source: MLA+ graphics, Google images.

Figure 39. The distance between tree rows depends on the growing crops and the harvesting equipment, and the change of crops during tree growth must be taken into account



Source: MLA+.

G Silvopasture

Description

This tool refers to the creation of single or group plantings of trees in pastures, creating forest-steppe or savannah-like ecosystems (Gold and Garrett 2021). Such a tool allows trees, shrubs, and fodder crops for livestock production to be grown on a single plot of land and also provide shade (Figure 40). The *Silvopasture Tool* supports the *Increased Tree Canopy Cover Approach*.

Figure 40. Silvopasture can help reduce heat stress, which improves animal performance and well-being

Protect
Protects the animals from temperature stresses

Create
Planting of trees, shrubs, and grasses

Source: USDA, National Agroforestry Center, Silvopasture, https://www.fs.usda.gov/nac/practices/silvopasture.php.

Co-benefits

- **Increasing the productivity of farmland** through the simultaneous production of livestock and wood products
- **Protecting animals from temperature stresses** that negatively affect weight gain, milk yield, and egg production
- **Providing additional fodder for livestock** in the growth of edible species of woody crops (leaves, branches, leaf, and fruit fall) and reduces temperature stress on forage grasses of the lower tier (Savanna Institute 2019).

What? How?[45]

- **Introduce woody species into pastures or by thinning an existing forest/wood plantation with the addition (or improvement) of a fodder component and strictly regulated grazing** (Jose, Kumar, and Walter 2017). Unmanaged grazing among tree stands is not a silvopastoral agroforestry system. Within the green corridor, it is more realistic to organize silvopasture (umbrella-like pastures) on private and long-term leased land with a legal land use intent for perennial plantings, to ensure the care and ownership of the planted trees. On public pastures, such format should be developed legally (who will be responsible and own the trees, responsibility in cases of damage, and so on) and overall adapt legislation to enable planting of sparsely planted trees on pasture land. These can also be private relatively small plots where trees/shrubs with edible foliage can be planted around the perimeter and cuttings, green leaves, and leaf litter used as supplemental feed. An animal and forage component can be added to horticultural systems.

[45] Expert opinion: N. E. Zverev, biodiversity specialist, Institute of Botany and Phytointroduction of Plants of Kazakhstan, Species selection for AF systems; O. A. Romanova, agroforestry specialist, KGU, Species selection for AF systems vision and selection of AF systems.

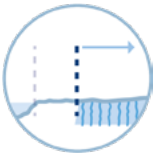
- **Establish a management and development plan for silvopasture.** That will account for irrigation, temporary protection of seedlings from grazing, and succession of forage species depending on the light available as the trees grow.
- **Improve pastures with planting of saxaul and perennial shrubs.** Saxaul planting should be in rows 5 m wide every 20 m. Perennial shrubs are planted in between the rows on strips 3 m wide every 4 m (Nechaeva and Prikhodko 1966). The remaining space in subsequent years will be filled by self-seeding. Crested wheatgrass (*Agropyron cristatum*) can be sown between saxaul strips throughout the latitude, and used for making hay for the winter period.

  The following is the recommended assortment for such pastures in the desert conditions of the green corridor: black saxaul (*Haloxylonam ammodendron*), white saxaul (*Haloxylon persicum*), forage kochia (*Bassia prostrata*), Pamirian winterfat (*Kraschenninnikovia ceratoides*); to improve the forage layer - bluebunch wheatgrass (*Pseudoroegneria spicata*) and crested wheatgrass (*Agropyron cristatum*) (Mukhammedov 1979).
- **Establish pilot plots where there are irrigation opportunities** to produce more valuable wood on pasture systems: white mulberry (*Morus alba*), red mulberry (*Morus rubra*), ponderosa pine (*Pinus ponderosa*), Pallas pine (*Pinus pallasiana*), Scots pine (*Pinus sylvestris*), and Austrian pine (*Pinus nigra*). For the herbs layer, use crested wheatgrass (*Agropyron cristatum*) in the first stages of tree growth, then transition to alfalfa (*Medicago sativa*) and clover (*Trifolium pratense*), with the formation of more shady conditions on tall fescue (*Festuca arundinacea*), creeping bentgrass (*Agrostis stolonifera*), and bluegrass (*Poa pratensis*). For horticultural silvopastures in GCAA, the following fruiting trees can be used: white and red mulberry, Ussurian pear (*Pyrus ussuriensis*), and common apricot (*Prúnus armeníaca*) (Mukhammedov 1979).

Where? Suitability consideration

Geographic areas
Rural
Landscape zone: deserts and meadows, steppes

Spatial zones
Zone 3: Area between buffers



Land Use
Agricultural use: agricultural use, pastures

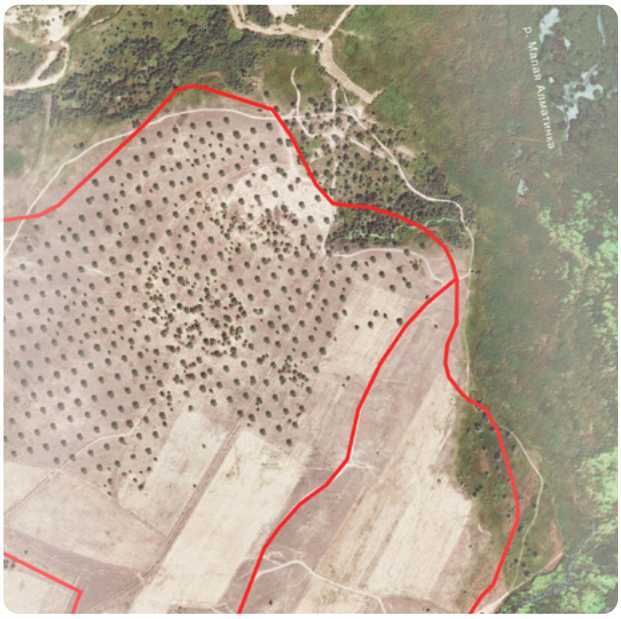
Visualization of the *Silvopasture Tool* in the Green Corridors context

Figure 41 shows the establishment of silvopasture in an agriculture plot (specified 03-046-221-416) along the Malaya Almatinka river. Trees create shade and a comfortable microclimate for animals. Plant shrubs can be planted between the trees for smaller animals. Young trees need to be protected from being eaten by livestock, for example, with a hedge (Figure 42).

Figure 41. A silvopasture along the Malaya Almatinka River

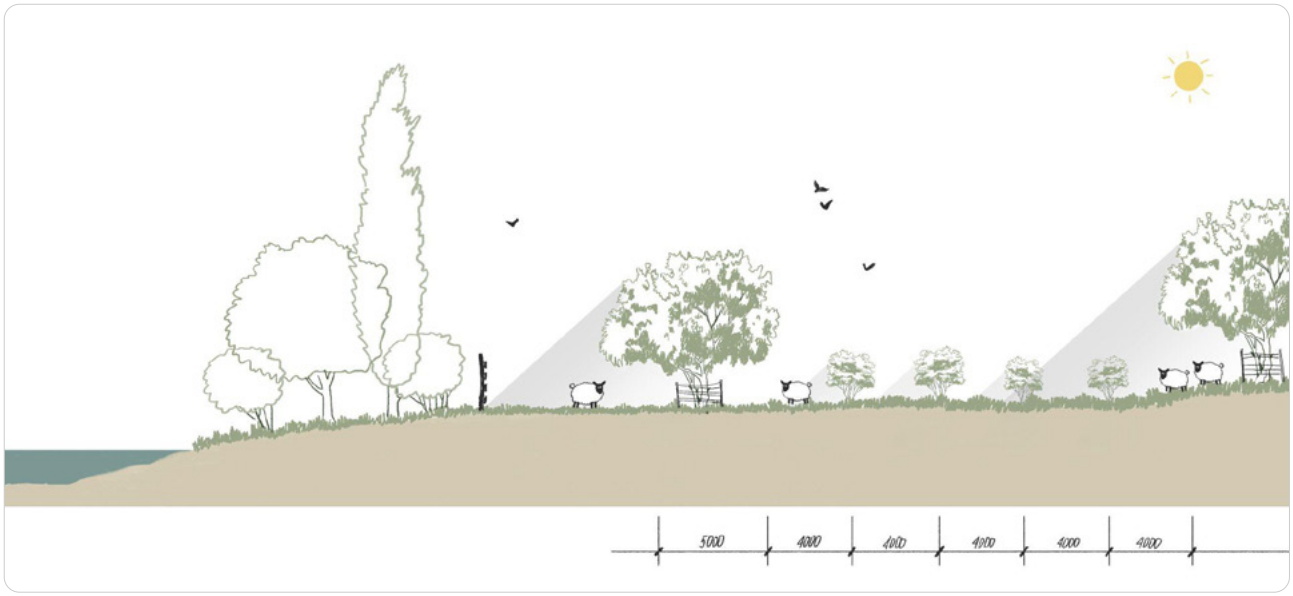
Before - a deforested area used for grazing livestock

After - silvopasture; planting trees to create shade and a microclimate for the animals



Location: https://goo.gl/maps/JeaJQ39hMweDueoW7.
Source: MLA+ graphics, Google images.

Figure 42. Typical section of a silvopasture



Source: MLA+.

2.4. Ecological Restoration and Enhancement Approach

Objective

Restore oppressed habitats as sustainable natural ecosystems and enhance local biodiversity in a city or beyond.

Slogans

"Making Green Corridors a Sustainable Home for Local Biodiversity!" or *"Bringing Life Back to the River Valleys"*

Challenges

Figure 43. Challenges mitigated by the Ecological Restoration and Enhancement Approach

Challenges

Canalization of riverbeds

Riverbank erosion, mudflow hazard

Loss of natural ecosystems

Source: MLA+.

Figure 44. Benefits of the Ecological Restoration and Enhancement Approach

Benefits

Mitigation of flooding risks

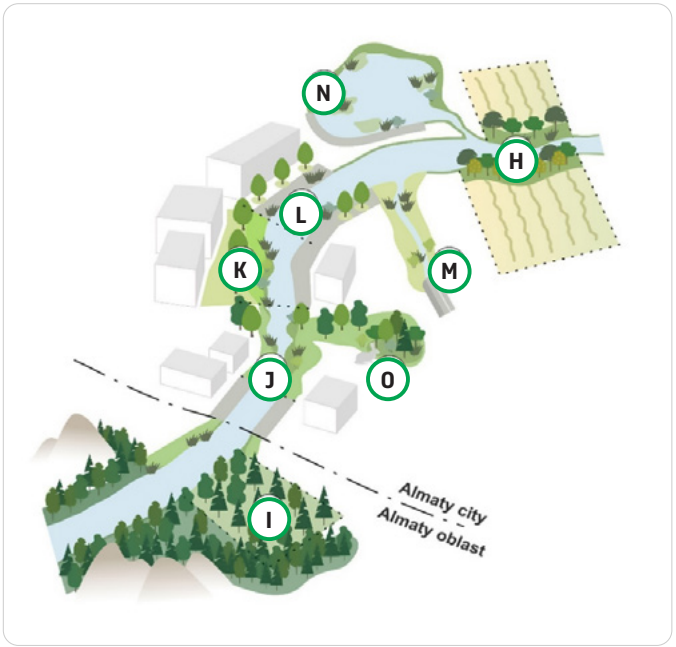
Habitat connectivity

Biodiversity

Source: MLA+.

Illustration of tools for this approach

Figure 45. Tools for the Ecological Restoration and Enhancement Approach



- **H** Riparian forest conservation and/or restoration
- **I** Foothills reforestation
- **J** Full river restoration
- **K** Single riverbank restoration
- **L** Artificial watercourse landscape enhancement
- **M** River daylighting
- **N** Aquatic biotopes
- **O** Terrestrial biotopes

Source: MLA+.

H Riparian Forest Conservation and/or Restoration

Description

This tool focuses on conserving, restoring, and/or reforesting riparian native forests (Figure 46). The tool implies conservation or restoration of native floodplain forest ecosystems called tugai forests that are typical for river floodplains in arid zones of Kazakhstan. The *Riparian Forest Conservation* and/or *Restoration Tool* supports the *Ecological Restoration and Enhancement Approach*.

Figure 46. Tugai forests downstream of the Syr Darya river, Kazakhstan

Protect
Create a protective barrier/ zone between riparian zones and manmade

Rehabilitate, Restore, Enhance
Conservation, restoration, or imitation of native floodplain forest ecosystems called tugai forests

Source: Visit Kazakhstan, https://dzen.ru/a/XxWONAZnOi5N6yUI.

Co-benefits[46]

- **Reduction in flow velocity.** Concrete riverbanks do not reduce the velocity of the mudflow but instead collect the entire flow into a directed straight channel. This increases the flow speed so mud and rocks reach the city. Natural valleys reduce water velocity and act as mudflow reservoirs (Pan, Liu, and Yang 2022).
- **Bank protection.** Native riparian forests can provide bank protection, as evidenced by several studies and projects. Riparian forests can stabilize stream banks and prevent erosion by reinforcing riverbank soils with tree roots (Abernethy and Rutherfurd 1999).
- **Ecological safety and protection of rivers** from nutrition surplus and other kinds of pollution that agriculture territories produce.
- **Ecological enhancement** by providing shade, shelter, and food for fish and other aquatic organisms; creation of the wildlife habitat and corridors for terrestrial organisms, improving aquatic and terrestrial habitats along waterways.
- **Reducing of the pollution** and nutrient surplus into water bodies.
- **Protection from flood** by giving rivers the space.

What? How?

- **Riparian forests conservation** which means protection of tree felling to clear the riverbanks for agriculture, construction, or landscaping. The preferred width of the riparian forest equals the width of the floodplain, but if conservation of the entire floodplain ecosystem is impossible, the minimal width should be at least 20 m. It is the minimum width for the wildlife habitat enhancement aim (University of Missouri 2013).

[46] For an overview of riparian forest buffers, see the USDA website: Riparian Forest Buffers.

- **Riparian forests reforestation, restoration, and rehabilitation,** where restoration of floodplain forests is possible as a commitment of Kazakhstan under the Paris Agreement with budgetary funds, as well as commercial carbon projects on leased land. Forest restoration should be carried out in those floodplain areas where the forest grew earlier. This requires surveys by landscape ecologists.

  Native plant species for the restoration of Tugai forests:

  Tree layer: laurel poplar (*Populus laurifolia*), black poplar (*Populus nigra*), silver poplar (*Populus alba*), *Populus diversifolia*, *Populus pruinosa*, *Fraxinus sogdiana*, almond willow (*Salix triandra*), bay willow (*S. pentandra*), white willow (*S. alba*), basket willow (*S. viminalis*), Russian olive (*Eleagnus angustifolia*) (Borissova, Nakladal, and Nurgaliyev 2017).

  Shrub layer: sea buckthorn (*Hippophae rhamnoides*), dogwood (*Cornus spp.*), tamarix (*Tamarix spp.*), honeysuckle (*Lonicera spp.*), barberry (*Berberis sphaerocarpa., B. iliensis*), wild rose (*R. beggeriana, R. acicularis, R. spinosissima*), raspberry (*Rubus idaeus*), dewberry (*R. caesius*) (Borissova, Nakladal, and Nurgaliyev 2017).

  Herb layer: club-rush (*Scirpus spp.*), narrowleaf cattail (*Typha angustifolia*), sedge (*Carex spp.*), meadowsweet (*Filipendula ulmaria*), Clematis (*Clematis spp.*), great burnet (*Sanguisorba officinalis*), common reed (*Phragmites australis*) and grasses (*Poaceae*) in higher terraces (Borissova, Nakladal, and Nurgaliyev 2017).

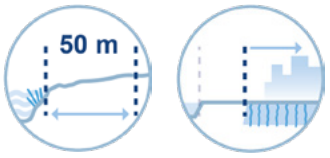
  The shrub vegetation rehabilitates faster than trees that are requiring several decades for their recovery. Therefore, the restoration first focuses on planting native fast-growing and high-productive tree species such as poplars and willows (Meshkov et al. 2009).

Where? Suitability consideration

Geographic areas
Urban, rural

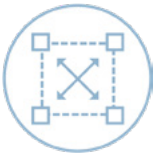
Landscape zone
river valley

Spatial zones
Zone 2.1: Natural riverbed buffer - 50 m from water edge
Additional requirement: The riparian forest grows only on river floodplains, so the width of the riparian forest is determined by the floodplain width. Floodplain, along with the river valley, should be marked out by the experts in river geomorphology and ecology.
Zone 3: Area between buffers
Additional requirement: Floodplain area has natural borders so it can be wider than 50 m and hit the area between buffers.



Zone 2.1 Zone 3

Technical specifications
Anthropogenic load: low anthropogenic load
Ecosystem type: riparian forests to be preserved.



Visualization of the *Riparian Forest Conservation and/or Restoration Tool* in the Green Corridors context

Figure 47 shows reforestation of the natural riparian forest ecosystem and regulation of chaotic vehicle and human trails in the valley of Malaya Almatinka River to the left of Zhetygen in Iliysk district.

Figure 47. Malaya Almatinka reforestation

Before - a river valley damaged by human activities

After - reforestation of riparian forests that provide ecological protection of river

Location: https://goo.gl/maps/z5nqM1q37vpNuKhg7.
Source: MLA+ graphics, Google images.

I Foothills Reforestation

Description

This tool focuses on restoration of the mountainous forest ecosystems or creation of the conditions for the forest to restore by itself (Figure 48). The *Foothills Reforestation Tool* supports the *Ecological Restoration and Enhancement Approach*.

Figure 48. The forest upstream of the Esentai

Protect
Retain water on slopes, mitigate mudflow hazards and soil erosion

Rehabilitate, Restore, Enhance
Restore the mountain forest ecosystem

Source: Google Street View, фото Tair KZ, https://www.google.com/maps/@43.656552,77.0836125,4164m/data=!3m1!1e3.

Co-benefits

- **Mudslides prevention.** A forest is the best natural way to retain water on slopes. The less the amount of water that flows down the mountains at one point, the less the erosion, and the ability of the water to carry the soil down the slope is also less. So, planting forests in deforested mountainous areas will help reduce mudflow hazard (Takashi, Sidle, and Richardson 2009).

What? How?

- Restoration of forest ecosystems of foothills, which are mostly spruce forests with juniper, willow, and caragana. In the wettest depressions grow spruce forests with understory of dog rose, honeysuckle, hawthorn, cinquefoils, and spirea. Birch, rowan, and aspen species could also be found in the tree layer.

  Native plant species of plants for montane reforestation near the rivers (Figure 50, Zone 1):

  Tree layer: Asian spruce (Picea schrenkiana), Siberian spruce (*Abies sibirica*), Tian Shan birch (*Betula tianschanica*), silver birch (*B. pendula*), Tian Shan rowan (*Sorbus tianschanica*) (Carpenter 2000).

  Shrub layer: hawthorn (*Cotoneaster sp.*), juniper (*Juniperus sp.*), caragana (*Caragana sp.*) (Carpenter 2000).

  Native plant species for montane reforestation on watersheds and slopes (Figure 50, Zone 2):

  Tree layer: Asian spruce (*Picea schrenkiana*), Siberian spruce (Abies sibirica), Tian Shan birch (*Betula tianschanica)*, silver birch (*B. pendula*), Tian Shan rowan (*Sorbus tianschanica*), aspen (*Populus tremula*), almond willow (*Salix triandra*), bay willow (*S. pentandra*), white willow (*S. alba*), basket willow (*S. viminalis*) (Goloskokov 1949).

  Shrub layer: hawthorn (*Cotoneaster sp.*), juniper (*Juniperus sp.*), caragana (*Caragana sp.*), honeysuckle (*Lonicera sp.*), dog rose (*Rosa sp.*), raspberry (*Rubus idaeus*), dewberry (*R. caesius*) (Pavlov and Polyakov 1940).

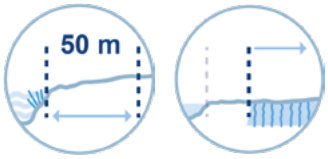
- **Rewilding**, or passive reforestation, is land preservation for the forests to grow back and a way to restore montane forest in huge areas where classic reforestation or planting can be difficult or too expensive (Montague 2020). Some research shows that the forest ecosystem that grew back is more sustainable than the planted one (Wang, Pedersen, and Svenning 2023). Rewilding should be controlled for invasive species.

Where? Suitability consideration

Geographic areas
Urban, rural

Landscape zone
Mountain meadows and forests, below subalpine and alpine meadows

Spatial zones
Zone 2.1: Natural riverbed buffer (50 m from water edge)
Zone 3: Area between buffers



Visualization of the *Foothills Reforestation Tool* in the Green Corridors context

Figure 49 shows forest restoration after deforestation in the foothills, near the Malaya Almatinka river, Gornaya Street. The restoration area was selected by analysis of the Global Forest Watch map service.[47] Roots of trees planted on slopes retard surface runoff, reduce erosion processes, and strengthen the soil, which affects the reduction of mudflow hazards. Zone 1 is the river valley and Zone 2 is a slope (Figure 50).

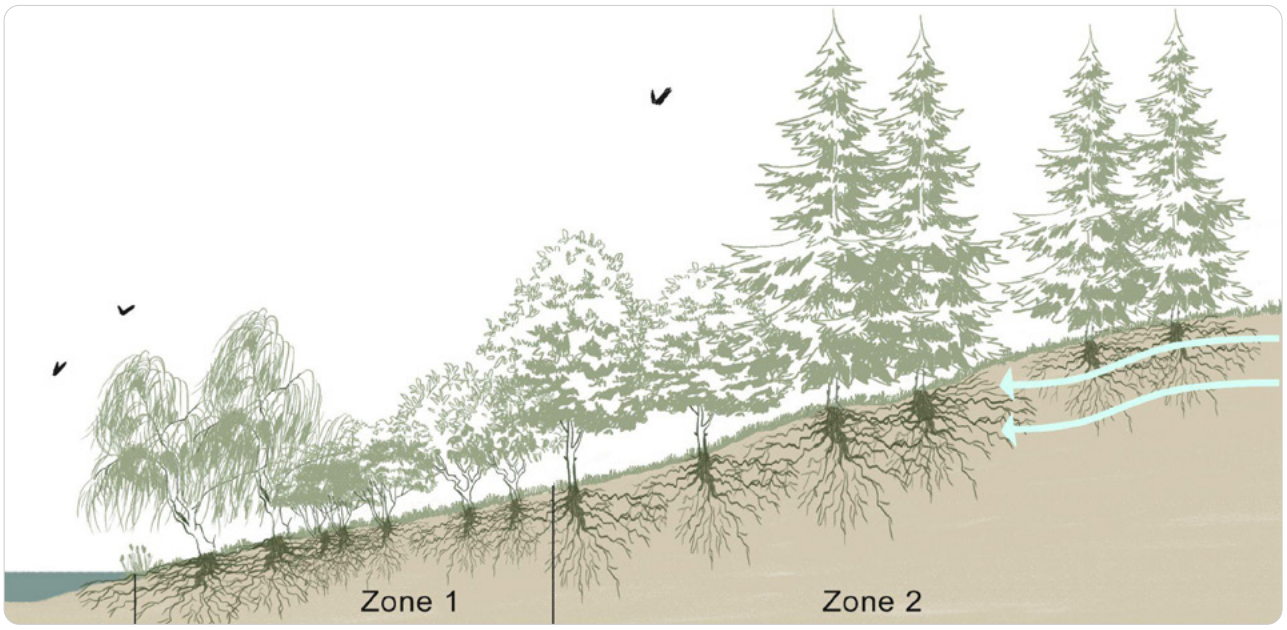
Figure 49. Slope reforestation

Before - deforestation of the slope

After - forest restored on the site, soil reinforced with the tree roots, retention of the surface flow

Location: https://goo.gl/maps/dWfhmU3bBpLwcxbU7.
Source: MLA+ graphics, Google images.

Figure 50. Visualization of the slope reforestation



Source: MLA+ graphics.

[47] GFW (Global Forest Watch). Interactive World Forest Map & Tree Cover Change Data https://www.globalforestwatch.org/map/.

J Full River Restoration

Description

This tool implies full restoration of the watercourse turning the concrete or gabion riverbed and both riverbanks to natural.[48] River restoration refers to a number of different approaches and techniques applied to enhance the natural state and functioning of rivers and catchments. Several terms are used to describe works aiming to improve the riverine environment—such as rehabilitation, re-naturalization, enhancement, re-creation, and mitigation—and river restoration is used as an umbrella term for these. The *Full River Restoration Tool* supports the *Ecological Restoration and Enhancement Approach*.

The Full River Restoration Tool supposes that the river should be restored closest to its natural watercourse, with use of native plant species in the riparian buffer. The riverbank protection is solved naturally through greenery, riprap, and natural erosion mats (Figure 51).

Figure 51. Stream restoration in Singapore

Protect
Reduce water velocity, mitigate mudflow hazards

Rehabilitate, Restore, Enhance
Restore the natural ecosystem of rivers

Source: Bishan-Ang Mo Kio Park, Singapore, image courtesy of Atelier Dreiseit, https://www.archdaily.com/964460/6-urban-design-projects-with-nature-based-solutions.

Co-benefits

- **Reduction in flow velocity.** Concrete riverbanks do not reduce the velocity of the mudflow but instead collect the entire flow into a directed straight channel. This increases the flow speed so mud and rocks reach the city. Natural valleys reduce water velocity and act as mudflow reservoirs (Pan, Liu, and Yang 2022).
- **Riverbank protection.** Reed beds help reduce the energy of the river and prevent riverbank erosion (Frankenberg 1997).

What? How?

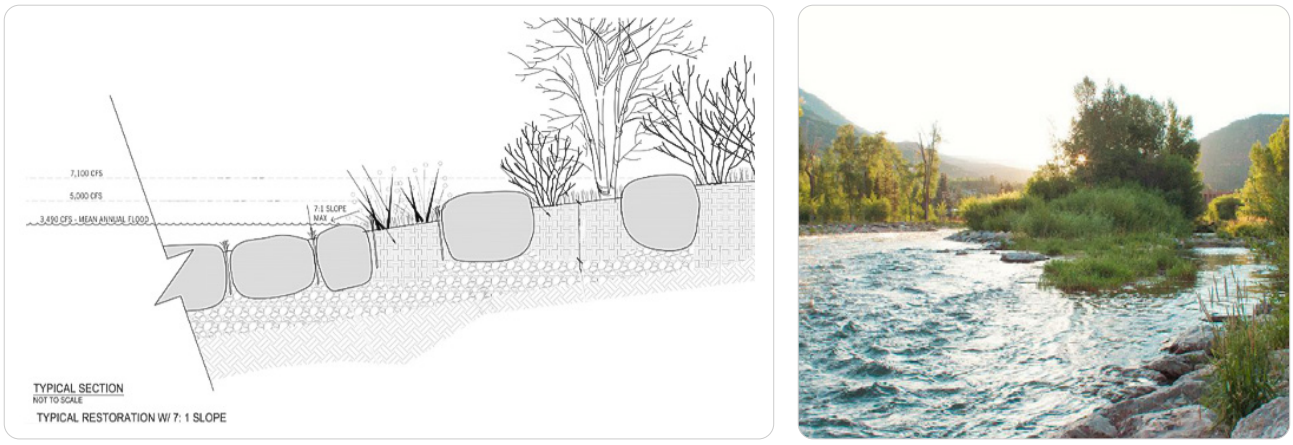
- **Choose a test plot.** All the changes connected with restoration should be tested in the Almaty context. All these design features are approved for rivers on plains but not in mountainous areas. The restoration design tools of this toolbox are re-designed for Almaty conditions but they should be approved with the Kazakh institution 'Kazselezaschita', which is engaged in ensuring the protection of regions, economic facilities, and the population from the effects of natural disasters.

[48] For a general definition of river restoration, see "What is river restoration?": River Restoration Factsheets | The RRC.

Then the design elements listed below should be established on a test plot to approve the safety and effectiveness in practice.

- **Make meanders.** It is better to design the meandering river course before valley development but not necessarily because rivers can meander by themselves if given some space. After removing the concrete, a new channel is dug through the lowest parts of the valley. The new channel has to be made within the old unstraightened channel that can be identified by the wettest areas. Riverbank toes should be protected with natural revetment. Then the new streambed needs natural cover: sand, loam, gravel, or boulders. This will prevent erosion and increase the river biodiversity.[49] It is necessary to remember that every river shifts its floodplain constantly so there should be free 'room for the river' to carve new paths over time.
- **Save steep slopes.** If the river valley has steep slopes, possibly with scree, and it does not threaten development or infrastructure, these slopes are worth saving. This is habitat for some birds and animals (such as hoopoes and swallows) (Kovshar 1988). To keep the slope from creeping, water should be diverted with ditches.
- **Do natural revetment.** Revetment type depends on the flow velocity, slope steepness, and site position.
  - ***Hard protection.*** Upstream water velocity is high and so is the threat of mudslides so there is a need to protect the watercourse. Upstream slopes and riverbanks should be reinforced with vegetated revetment: concrete blocks, gabions, or riprap. Riprap is the best as it looks natural (Figure 52). The size of the planting holes determines greenery that will grow in riprap. Small holes are enough for grass. Large ones are better for bushes and trees that are more valuable. The size of boulders depends on the flow velocity. The riprap should be placed on a suitable permeable material like sand, gravel, or fabric to keep the soil under the boulders (MASSDEP 1997).
  - ***Soft protection.*** In low-flow velocity areas (except riverbank toes), it is better to use cheap biodegradable permeable materials for slope reinforcing, such as coir mats and coir rolls (Figure 53) (Roca et al. 2017). Vegetation will grow through such material and fix the riverbanks naturally.

Figure 52. Riprap with planting holes



Source: DHM Design, Basalt river restoration, 2017. https://express.adobe.com/page/1SeR0EgHeV5t9/.

[49] The River Restoration Centre. Manual of River Restoration Techniques. Restoring meanders to straightened rivers.

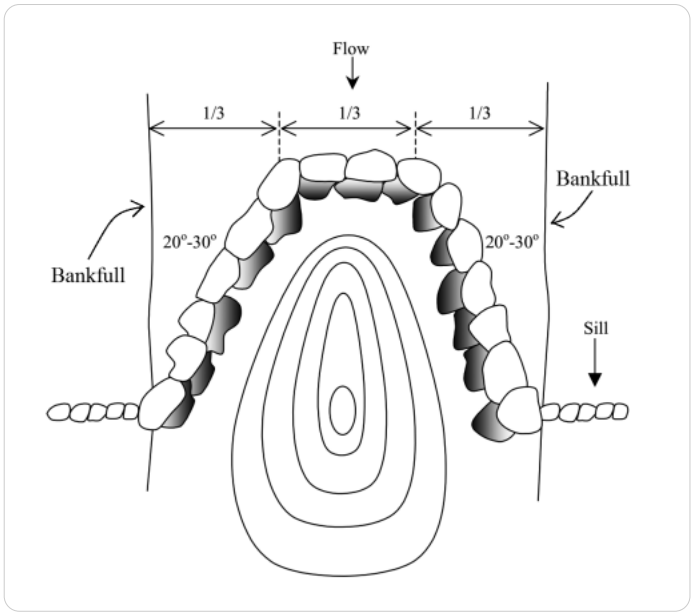
Figure 53. Coir mats and rolls

Source: Salix, https://www.salixrw.com/products/.

- **Place sills, backwaters, and shallows.** A flow speeds up in a channel without barriers. The higher the flow rate, the more solid material the river can carry and the more dangerous it is. The fast current also erodes riverbanks. Furthermore, a big part of river inhabitants do not live in fast currents.

  The *sills*, *vanes*, or *rapids* divert the current from the riverbanks to the center of the channel. It protects the slopes from erosion. Diverted current forms backwaters and shallows where river fauna can live and spawn. Also, the flow rate decreases in backwaters, so suspensions with pollutants become sediments and water purifies. The system of river backwaters and shallows recreate lost habitats, increase the river attractiveness, and reduce erosion.

Figure 54. J-hook vane (in plan)



Full stream restoration assumes that sills are made with boulders and tree parts that are also a habitat for fish and aquatic fauna. Sills should be J-shaped and the lower part should be directed downstream so it diverts water to the channel center. It reduces riverbank erosion but speeds up the flow (Hickman and Thompson 2010) (Figure 54).

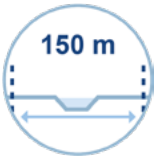
Source: Fleming, Vogel, and McLemore 2017. https://extension.okstate.edu/fact-sheets/print-publications/bae/natural-stream-restoration-and-enhancement-bae-1526.pdf.

Where? Suitability consideration

Geographic areas
Urban, rural

Landscape zone
River valley

Spatial zones
Zone 4: Two-sided concrete riverbed buffer



Land Use
The area should be undeveloped or with the possibility for transformation. There should not be any infrastructure like roads or utilities or it must be possible to relocate the infrastructure.

Technical specifications
Dimensions: The width of the valley for restoration should be specified by the experts in riparian ecology and geomorphology.
Flood risk: low mudflow hazard, below the mudflow reservoirs.

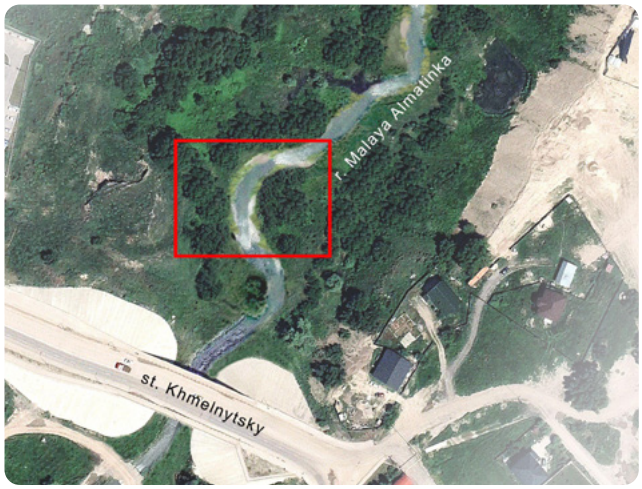
Visualization of the *Full River Restoration Tool* in the Green Corridors context

Figure 55, 56, and 57 show the restoration of Malaya Almatinka river between Bogdan Khmelnitsky Street and Bukhtarmirsky Street in the micro-districts Zhas Kanat, Mayak, and so on, with the creation of meanders, rapids, and backwaters and with restoration of floodplain forests.

Figure 55. Full restoration of the Malaya Almatinka valley

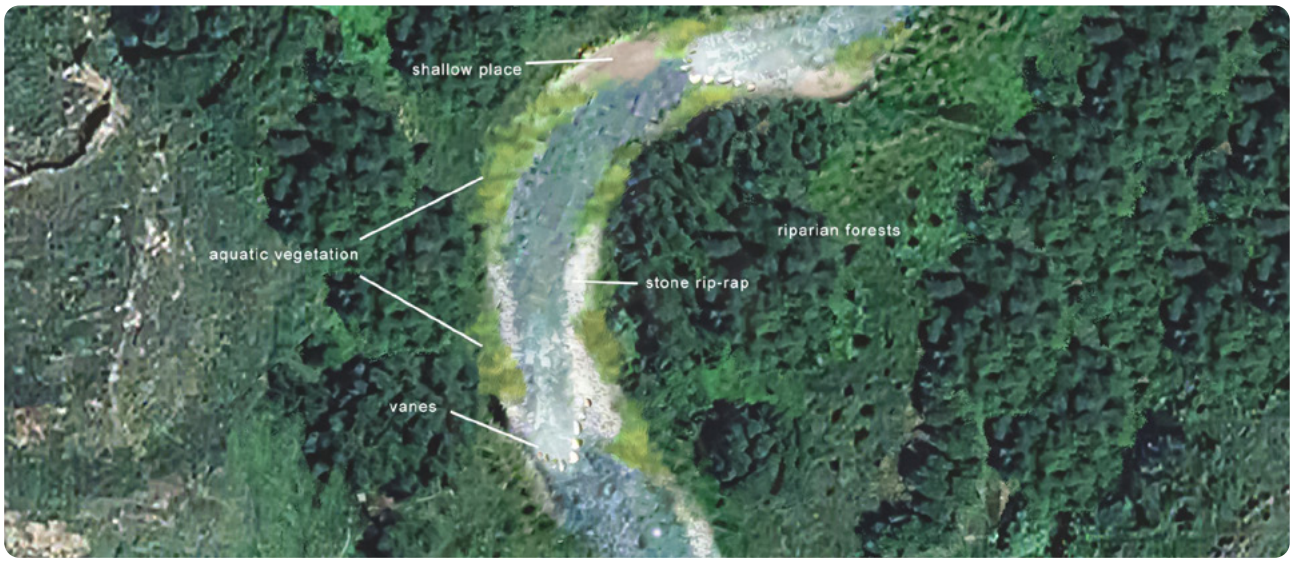
Before - the straightened channel of Malaya Almatinka below Bohdan Khmelnitsky Street

After - the naturalized channel of Malaya Almatinka with meanders, sills, and riparian forests restored



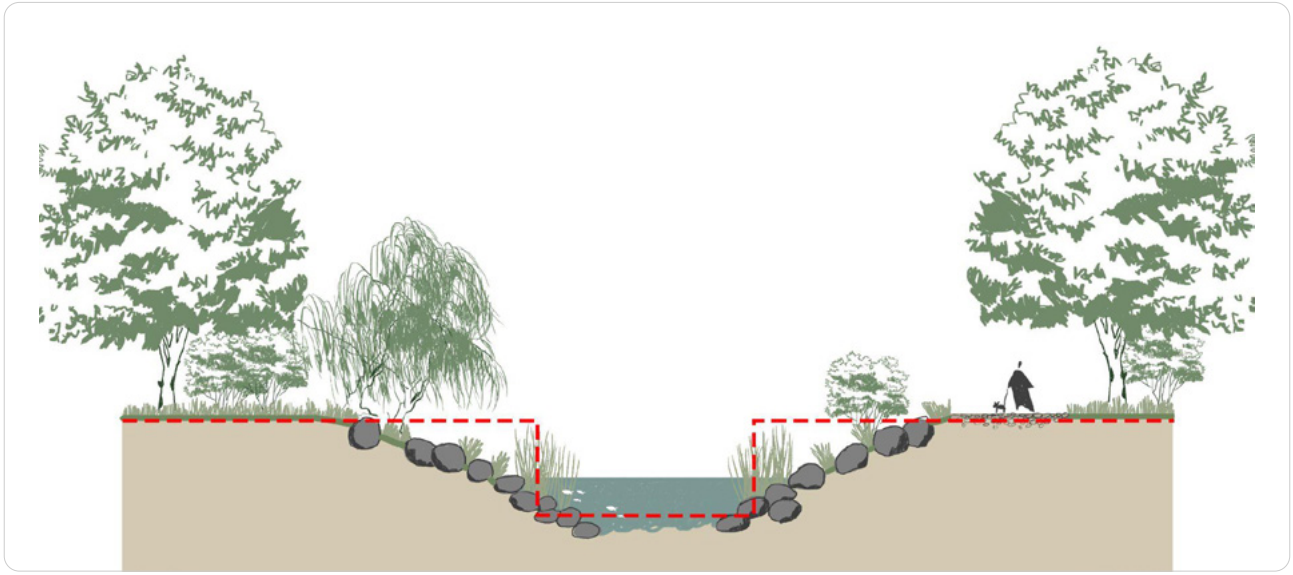
Location: https://goo.gl/maps/hTKxrVnPBbgMTiWc6.
Source: MLA+ graphics, Google images.

Figure 56. Fragment of the naturalization of the river, applying the techniques described in the 'How?' section



Source: MLA+ graphics, Google images.

Figure 57. Reconstructed channel of the Malaya Almatinka



Source: MLA+ graphics.
Note: Dotted line shows the existing profile.

K Single Riverbank Restoration

Description

This tool assumes partial naturalization when one of the riverbanks is restored. For the definition of river restoration, see tool *J. Full River Restoration.* Single riverbank restoration is appropriate where full restoration is not possible, for example, when a building or street is adjacent to one riverbank. In the *Single Riverbank Restoration Tool*, the concrete or gabions on one riverbank are removed and replaced with nature-like riverbank protection (for example, as in the *Permanente Creek re-naturalization project*, Figure 58). The *Single Riverbank Restoration Tool* supports the *Ecological Restoration and Enhancement Approach*.

The *Single Riverbank Restoration Tool* assumes that the one riverbank should be restored with native plant species in the riparian buffer. The riverbank protection is natural, with riprap, erosion mats, and greenery.

Figure 58. Partial re-naturalization project for Permanente Creek in Canada: comparison between the current situation (top picture) and the conceptual rendering (bottom picture).

Protect
Reduce water velocity, mitigate mudflow hazards

Rehabilitate, Restore, Enhance
Restore the natural ecosystem of rivers

Source: WRA Environmental Consultants, September 2020. Permanente Creek, Conceptual Alternative Analysis, 8. Reference projects: p. 11 https://dokumen.tips/documents/matadero-creek-renaturalization.html?page=18.

Co-benefits

- **A compromise solution between ecological restoration projects and the economy of the resources.** This approach is more flexible and may require less financial and time investment than restoration of both riverbanks.
- **Creation of additional space on the embankment.** Changing the shape of the slope from a diagonal to a vertical wall gives more space to pedestrians.

What? How?

- **Choose a test plot.** All the changes connected with restoration should be tested in the Almaty context. All these design features are approved for rivers on plains but not in mountainous areas. The restoration design tools of this toolbox are re-designed for Almaty conditions but they should be approved with the Kazakh institution 'Kazselezaschita', which is engaged in ensuring the protection of regions, economic facilities, and the population from the effects of natural disasters. Then the design elements listed below should be established on a test plot to approve the safety and effectiveness in practice.
    - **Make a stream valley wider.** Change the profile of the riverbed and embankment by removing the retaining walls or by moving one of them further from the stream.
    - **Do natural revetment.** Natural riverbank reinforcement depends on the configuration of the riverbank that remains artificial because it will strongly affect erosion processes. The riverbank protection method is also selected depending on the river flow rate and the site location (Figure 59). For more information, refer to *J. Full River Restoration Tool.*

Figure 59. A successful compromise in the upper Esentai - the riverbank is made with gabions; the other is naturally preserved with the use of a rock outline

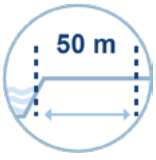
Source: Google Street View.

- **Place rapids, backwaters, and shallows.** They are important for the natural components of the river and reduce erosion (see *J. Full River Restoration Tool*). Vanes should be made of natural materials or combined with concrete for hardness of construction. Formation of shallows and backwaters will depend on the water current, and the current will follow the configuration of the hard riverbank; it is worth considering when designing natural riverbank protection.

Where? Suitability consideration

Geographic areas
Urban
Landscape zone: river valley

Spatial zones
Zone 2.2: Concrete riverbank buffer (50 m from water edge)



Land Use
The area should be undeveloped or with the possibility for transformation. There should not be any needed infrastructure like roads or utilities or it must be possible to relocate the infrastructure.

Technical specifications
Dimensions: sufficiently wide riverbanks; then the river may change the direction of flow and overflow in spring. The required width is calculated according to the degree of flooding of the area.
Flood risk: low mudflow hazard

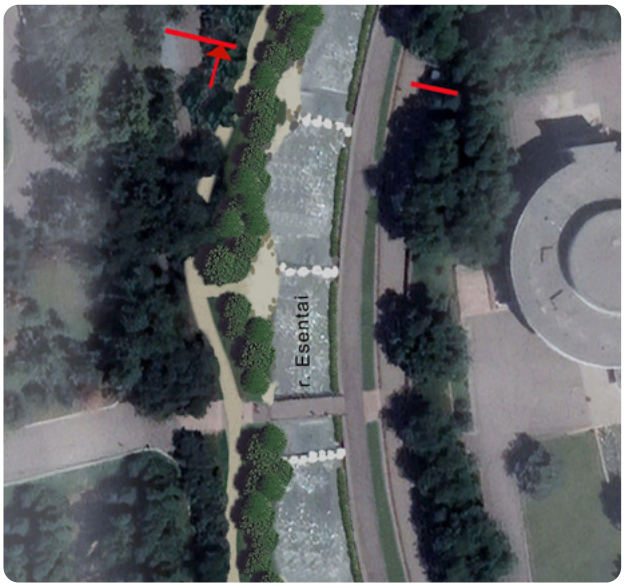
Visualization of the *Single Riverbank Restoration Tool* in the Green Corridors context

The figure shows restoration of the left bank of the Esentai river in the garden square of the Kazakh National Academic Drama Theater, using nature-like riverbank protection — the riprap. Also, a path is created near the water and floodplain vegetation is planted on the riverbank (Figure 60).

Figure 60. Restoration of one bank of the Malaya Almatinka river

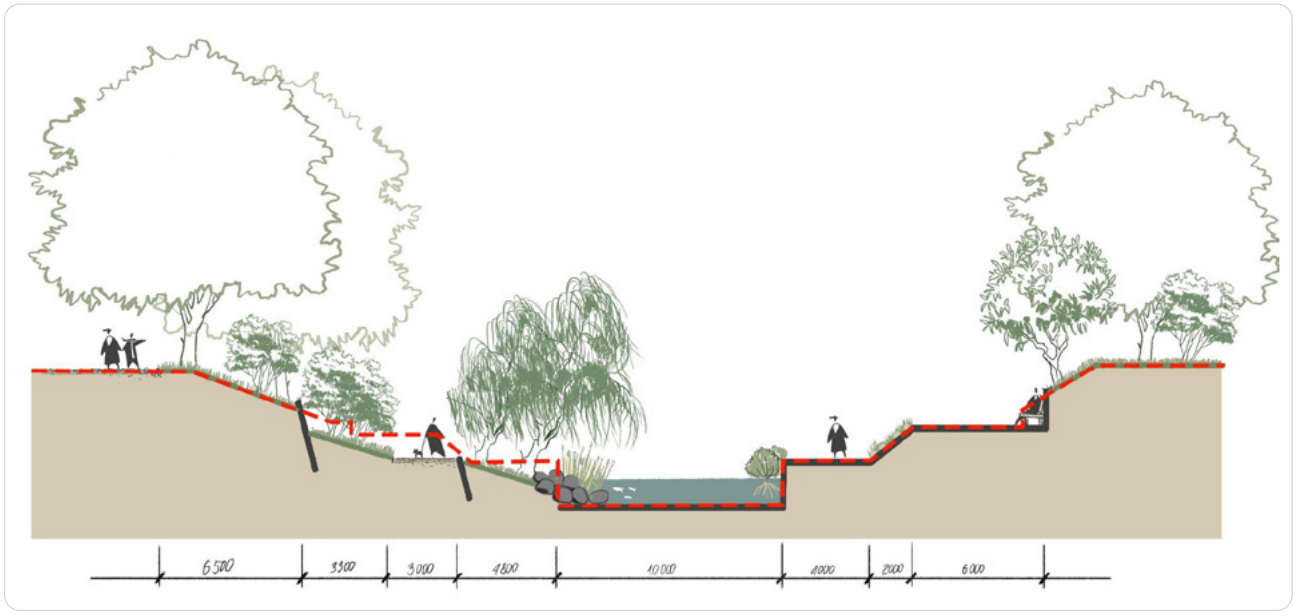
Before - the concrete banks of Esentai river

After - restoration of the left riverbank near National Academic Drama Theater



Location: https://goo.gl/maps/X6Z72EDympJwhmWW7.
Source: MLA+ graphics, Google images.

Figure 61. Natural riverbank protection with riprap



Source: MLA+ graphics.
Note: More gentle slope is created and approaches to water appear. Additional floodplain trees and shrubs are planted and the existing slope profile on which trees grow is preserved. The dashed line shows the existing profile of Esentai river.

L Artificial Watercourse Landscape Enhancement

Description

This tool enhances the greening of artificial riverbeds. The tool is used when full or partial naturalization of river channels is not possible due to the proximity of development or the protection status of concrete riverbank stabilization. For the definition of river restoration, see *J. Full River Restoration Tool.*

Artificial riverbeds are improved through the addition of natural elements to concrete channels: stones, rapids, and shallows with vegetation. Change of channel profile and greening are welcomed besides recreational features (Figure 62). The *Artificial Watercourse Landscape Enhancement Tool* supports the *Ecological Restoration and Enhancement Approach.*

Figure 62. Los Angeles River Revitalization Master Plan

Protect
Reduce water velocity, mitigate mudflow hazards

Rehabilitate, Restore, Enhance
Restore the natural ecosystem of rivers

Source: Wenk Associates, Los Angeles River Revitalization Master Plan, 2007, https://www.wenkla.com/projects/los-angeles-river-revitalization.

Co-benefits

- **A compromise solution between ecological restoration projects and the economy of the resources.** This approach is more flexible and may require less financial and time investment than restoration of both riverbanks.
- **Creation of additional space on the embankment.** Changing the shape of the slope from a diagonal to a vertical wall gives more space to pedestrians (see Figure 62).

What? How?

- **Choose a test plot.** All the changes connected with artificial watercourse enhancements should be tested in the Almaty context. All these design features are approved for rivers on plains but not in mountainous areas. The restoration design tools of this toolbox are re-designed for Almaty conditions but they should be approved with the Kazakh institution 'Kazselezaschita', which is engaged in ensuring the protection of regions, economic facilities, and the population from the effects of natural disasters. Then the design elements listed below should be established on a test plot to approve the safety and effectiveness in practice.
    - **Change the shape of the steep slope.** Slopes angled at 45° are an inefficient use of space and have some disadvantages like surface flow that leads to erosion. Terracing steep slopes with retaining walls provides some space for greenery and pedestrian paths. So, if the riverbed is going to be reconstructed, the option of changing the profile from a steep diagonal slope to a straight wall should be considered (DPD 2019). This area can get flooded, so the greenery and infrastructure must withstand spring floods (Figure 63).

Figure 63. The Cheonggyecheon River, Seoul, Republic of Korea, is a good example of artificial riverbed improvement in an urban environment

Source: Bloomberg, Reclaiming Nature through Urban Parks, https://www.bloomberg.com/news/articles/2016-04-02/reclaiming-nature-through-urban-parks-best-cityreads-of-the-week.

- **Change the shape of the riverbed.** If the riverbed is going to be reconstructed, it should be reprofiled with the creation of shallows. The river can flow in a narrow, deep channel even in summer when the water level is extremely low (Figure 64). On sites below the mudflow reservoirs, it is preferrable to preserve the shallows that rivers form naturally (Figure 65). These deposits are typically cleaned out of artificial river cascades, but do not let shallows become too large. They contribute to biodiversity and visual appeal: aquatic and riparian flora and fauna live in these shallows. Channels should be narrowed sinuously to look like a natural stream.[50]

Figure 64. Berm creation during construction and one year later, showing vegetation colonization on River Somer in Midsomer Norton in Somerset, England

Source: Woodland Water & Gardens and D. Longley, 2011–2012; Manual of River Restoration Techniques, River Somer, Placing Berms: Enhancing Straightened River Channels.

[50] The River Restoration Centre. *Manual of River Restoration Techniques. Modifying River Bed Levels, Water Levels and Flows:*
River Bure, placing trees: Modifying River Bed Levels, Water Levels and Flows
River Darent, placing gravel: Modifying River Bed Levels, Water Levels and Flow.

Figure 65. Even concreted, the Big Almatinka forms shallows like a natural river

Source: Google Street View.

Do natural revetment. Instead of solid concrete, use vegetated concrete blocks or vegetated gabions (Figure 66). Soft materials like coir erosion mats can be used on upper slopes that do not flood every year.

Figure 66. Embankments of Esentai river: solid concrete slope and vegetated concrete slope

Source: Google Street View.

- **Place fixed rapids.** Rapids or vanes are important for nature-like river flow and reduce erosion (see *J. Full River Restoration Tool*). Vanes can be made from concrete (so it is desirable to shape them to be natural and turn at an angle to the direction of the flow) or from boulders. If the flow on site is high and there is a mudflow hazard, boulders can be fixed with metal anchors in concrete. Rapids should be J-shaped and the lower part should be directed upstream so it diverts water to the reinforced riverbanks. It does not reduce riverbank erosion but slows down the flow (Hickman and Thompson 2010).
- **Make the walls green.** Green spaces along vertical surfaces such as retaining walls, buildings, and fences. Greenery is planted along the wall to cover it or vine along it (Figure 67).
- **Maintain mudflow protection systems.** All man-made river channel improvement techniques are implemented with analysis of the existing condition, modernization, and regular cleaning of mudflow protection systems. This will make natural beautification safe for the city.

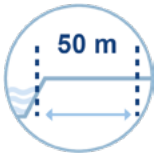
Figure 67. The green wall along the recreational route on Malaya Almatinka river

Source: Google Street View.

Where? Suitability consideration

Geographic areas
Urban
Landscape zone: river valley

Spatial zones
Zone 2.2: Concrete riverbank buffer (50 m from water edge)



Land Use
The area should be undeveloped or with the possibility for improvements.

Technical specifications
Location: where full restoration is not possible: buildings or streets are too close to the shoreline
Flood risk: low mudflow hazard

Visualization of the *Artificial Watercourse Landscape Enhancement Tool* in the Green Corridors context

Figure 68 and Figure 69 show improvement of the concrete channel of Bolshaya Almatinka river between Zhandosova and Toraigyrov Streets. The vegetated riprap, rapids, and aquatic plants were placed on site in addition to recreational infrastructure — benches and approaches to water.

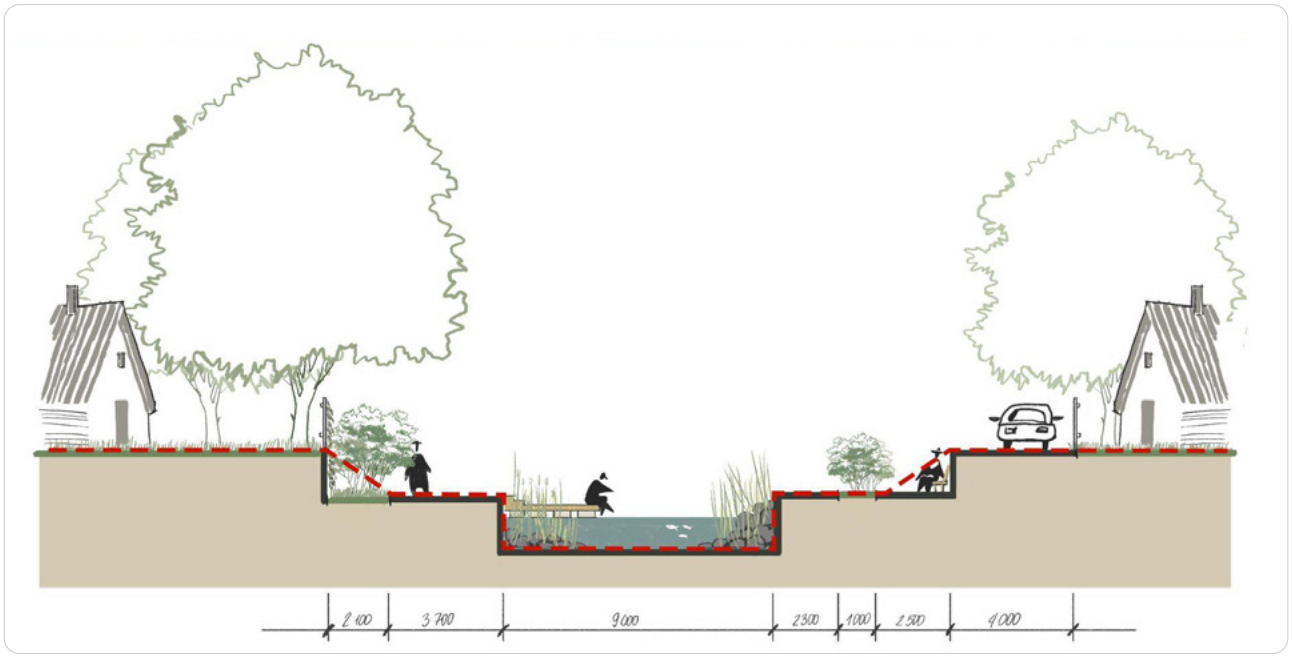
Figure 68. Improvement of the Bolshaya Almatinka artificial riverbed

Before - concreted riverbed of Bolshaya Almatinka river

After - improved vegetated riverbed of Bolshaya Almatinka river

Location: https://goo.gl/maps/WZMzBu1fGzwcM8it6.
Source: MLA+ graphics, Google images.

Figure 69. Changing the profile of the slopes from a diagonal to a straight wall to make more space for pedestrian paths along the waterfront



Source: MLA+ graphics.
Note: Additional reinforcement with riprap was made. Retaining walls were vegetated, and recreational elements were created. Trees were planted on private plots along the waterfront. The dashed line shows the existing profile of Bolshaya Almatinka.

M River Daylighting

Description

This tool refers to the re-naturalization of a culverted stream (Figure 70) (American Rivers 2007). The *River Daylighting Tool* supports the *Ecological Restoration and Enhancement Approach.*

Figure 70. Van Der Donck Park, City of Yonkers, New York, USA.

Protect
Reduce water velocity, mitigate mudflow hazards

Rehabilitate, Restore, Enhance
Restore the natural ecosystem of rivers

Source: Kensinger, Nathan. 2016. "Daylighting the Saw Mill River." December 15, 2016. https://ny.curbed.com/2016/12/15/13963898/yonkers-saw-mill-river-photo-essay.

Note: The Saw Mill River was buried under urban development. The culvert was preserved due to flood protection and the main stream was diverted to the park that was created; 1,300 m^2 of new aquatic habitat attracted fauna species such as turtles, ducks, fish, blue crab, American eel and more.

Co-benefits

- **Increase in the flow capacity.** A culverted river has a low flow capacity. If floods or mudflows occur, the culvert becomes a barrier to flow, causing extreme flooding situations for nearby areas. After every mudflow, the culvert pipe should be cleaned of stones and sediments. Insufficient maintenance during repeated mudflows can lead to demolition of the culvert and damage of the property (Figure 71).
- **Creation of the new green space.** River de-culverting is an opportunity to create a new park.

Figure 71. Culverted Zharbulak river under the new residential complex 'Europolis' on Omarova Street.

Source: Aimbetova, Madina. 2021. "The River in a Vice." Newspaper 'Vremya', April 16, 2021.
https://time.kz/articles/risk/2021/04/16/reka-v-tiskah.

What? How?

- **Make an agreement with landowners.** Rivers are usually culverted to put some business objects above them. Even if they are not, the land above the culvert is a point of conflict of interests, so the legal aspect should be solved before daylighting the stream.

- **Remove concrete and restore.** Daylighting includes the exposure of a buried river or stream and restoration of the natural watercourse and functions (see *J. Full River Restoration Tool*). Therefore, some landscape transformations should be made: removal of concrete or other materials covering the river, expansion and creation of a more natural riverbed, and riparian vegetation.

Where? Suitability consideration

Geographic areas
Urban

Spatial zones
Zone 3: Area between buffers
On sites above culverts

Land Use
Areas that can be transformed (for example, car parks, industrial areas). There should not be any infrastructure like roads or utilities or it must be possible to relocate the infrastructure.

Technical specifications
Location: where full restoration is not possible: buildings or streets are too close to the shoreline
Flood risk: low mudflow hazard

Visualization of the *River Daylighting Tool* in the Green Corridors context

Figure 72 shows the opening, encased in a pipe, of the Boralday River at the storage area site 20-321-030-446, with an attractive park area on the riverbank. For land rezoning, there are different ways of encouraging landowners, including changing the functional zone or building density.

Figure 72. The opening of Boralday River

Before - section of the storage area; the Boralday River flows in a pipe underground

After - opening up the river; with creation of an attractive green space, the land has urban development potential

Location: https://goo.gl/maps/YXh5CHYnacW6k6GTA.
Source: MLA+ graphics, Google images.

N Aquatic Biotopes

Description

This tool refers to the creation of aquatic habitats. For development / enhancement of aquatic ecosystems, consider creation of shallow waters with hydrophytes and flat banks of water bodies (Figure 73). The *Aquatic Biotopes Tool* supports the *Ecological Restoration and Enhancement Approach*.

For restoring aquatic ecosystems that were damaged or destroyed by anthropogenic activities or natural accidents, refer to the tools connected with ecological restoration (Tools H, J, K).

Figure 73. Woodberry Wetlands reedbeds during and after installation. London, UK.

Protect
Bank protection: aquatic vegetation helps reduce current velocity and the potential for bank erosion

Rehabilitate, Restore, Enhance
Restore natural ecosystems of water resources damaged or destroyed as a result of anthropogenic activities or natural accidents

Create
Create new aquatic habitats

Source: Salix, https://www.salixrw.com/solution/woodberry-wetlands/.

Co-benefits

- **Aquatic biodiversity enhancement.** There are no shallow waters near Almaty where waterfowl and other aquatic inhabitants could live. Creation of such ecosystems will increase species diversity in the agglomeration (Kovshar 1988).
- **Bank protection.** Reed beds help reduce the flow of the river and prevent bank erosion (Frankenberg 1997).

What? How?

- **Make shallows and plant hydrophytes.** Reeds and other hydrophytes grow in water, but at shallow depths, so water spaces no more than 1.0–1.5 m deep should be created to provide ideal conditions for the growth of such grasses. If planting in the ground is not possible, a 'floating island' format can be used (Figure 74).

Figure 74. Aquatic biotope near the metal bank

Source: Department of Planning and Development. 2019. "Vertical Bulkhead or Seawall Treatments." Chicago River Design Guidelines, p. 36.

- **Make gentle banks and ladders.** Frogs and toads are useful because they eat harmful insects. They need pools of standing water that do not dry up in summer and do not freeze over during winter. To help young animals get out of artificial reservoirs with steep or concrete banks, consider building ladders with a width of at least 1 m and a slope of no more than 50°. The banks of natural reservoirs should be gentle, with soft ground and shallow water (Kovshar 1988).

Where? Suitability consideration

Geographic areas
Urban, rural

Spatial zones
Zone 1: Waterway

Land use
Ponds, reservoirs, rivers, all water bodies

Technical specifications
Dimensions: shallow depth
Anthropogenic load: low anthropogenic and technogenic load
Flood risk: slightly changing water level, regulated currents

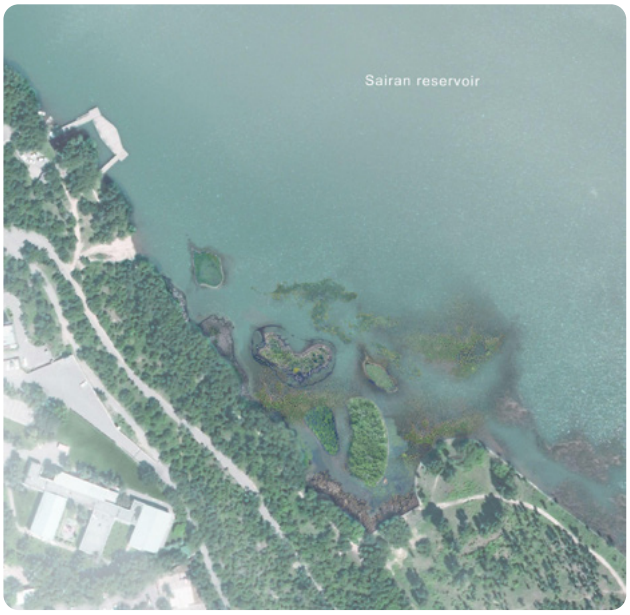
Visualization of the *Aquatic Biotopes Tool* in the Green Corridors context

Figure 75 shows the creation of aquatic habitats at Sairan Reservoir.

Figure 75. Shallows created with aquatic vegetation on Sairan Reservoir

Before - Sairan Reservoir

After - establishment of riparian vegetation, aquatic biodiversity, and bird houses; ecotourism potential for urban dwellers at Sairan Reservoir



Location: https://goo.gl/maps/ATU3togadkD5ZzKc7.
Source: MLA+ graphics, Google images.

0 Terrestrial Biotopes

Description

This tool refers to the creation of terrestrial habitats. Terrestrial biotopes are natural or seminatural areas created to increase biodiversity. It can be increased artificially by creating conditions for certain species (Figure 76). These novel ecosystems may be suitable habitat analogues for native plant species of conservation interest (Itani 2020).

The famous example of forest biotope creation is the Miyawaki method (Miyawaki 1999). It is a technique used for creating small-scale, native forests that grow rapidly and are extremely dense. The technique has been used in various reforestation and afforestation projects around the world to create biodiverse, native forests in a short period. The method involves planting a large number of native tree species in a small area, which leads to the rapid growth of a dense, multilayered forest.

Not only forests can be re-created in urban areas. Meadow biotopes are quite popular, effective for urban biodiversity boost, and suitable for Almaty (Bjørn et al. 2019). The geography of the city determines which biotopes are suitable for it.

The *Terrestrial Biotopes Tool* supports the *Ecological Restoration and Enhancement Approach*. This tool considers only the creation of terrestrial habitats. For restoring ecosystems that were damaged or destroyed by anthropogenic activities or natural accidents, refer to the tools connected with ecological restoration (Tools H, J, K).

Figure 76. (a) A good example of a diverse ecosystem by the waterfront, represented by grasses, shrubs, trees, flowers—a home for animals and birds. (b) A poor example of traditional row planting of trees, without different plant tiers.

a

b

Protect
Protect habitats, native species

Rehabilitate, Restore, Enhance
Restore damaged or destroyed natural ecosystems of water resources

Create
Create new habitats

Source: Friends of Chicago River, case studies, resources, and examples for river edge development, p. 8.

Co-benefits

- **Increase in the amount of useful terrestrial species.** Birds, insects, and bats eat insect pests. Birds and bats make it easier to maintain green areas by eating fallen fruits and dispersing seeds.[51] Insects pollinate plants.[52] Bats also eat pests and carry seeds.[53]
- **Ecosystem services.** Terrestrial habitats provide important ecosystem functions such as soil formation, climate regulation, and air quality improvement.[54]
- **Creation of leisure places.** Terrestrial biotopes are popular recreational zones for people. They also have cultural and aesthetic value associated with their unique flora and fauna, landscapes, and traditions tied to local communities.

What? How?

- **Create biotopes.** Different biotopes are homes for different species and vegetation layers. The main biotopes for Almaty rivers should be forest, meadow, and riparian.

[51] Why Birds Matter website #BringBirdsBack: https://www.3billionbirds.org/why-birds-matter.

[52] Buglife website - Pollinator: https://www.buglife.org.uk/bugs/love-bugs/pollinators/.

[53] Why Bats Matter website - About Bats - Bat Conservation Trust: https://www.bats.org.uk/about-bats/why-bats-matter.

[54] For a general overview of ecosystem services, see the official page of the United Nations Economic Commission for Europe (UNECE): Ecosystem Services | UNECE.

- ***Forest biotope*** involves multiple layers of vegetation, from large trees to herbs. In forests, the leaves and roots of trees, shrubs, and grasses are in different layers, which helps each get its own amount of light, water, and nutrients from the soil. Layering increases species diversity and reduces species competition, which ensures a greater percentage of plant survival.

  Forest biotopes have more layers than urban greenery (Ametov et al. 2016):

  - Tree layer: first layer — high trees
  - Second layer — low trees and large shrubs
  - Shrub layer: third layer — medium shrubs
  - Fourth layer — low shrubs
  - Herb layer: fifth layer — high herbs
  - Sixth layer — high herbs, mosses, lichens, and groundcover plants.

  The distribution is conditional, since the layer determines not only the type of plant but also its variety, shape, and climatic conditions of growth. Forest biotopes are home to birds and small mammals because of their density. Plant species for biotope creation depends on the type of forest; see 2.3 *Increased in Tree Canopy Cover Approach*.

- ***Meadow biotope*** consists mainly of various herbaceous plants, including perennials. This can be an artificial analogue of the steppe ecosystem. Such biotopes become a good food base for insect pollinators. Vegetation for meadow biotopes that can live in urban conditions should be selected with a geobotanist in a separate study.

- ***Riparian biotopes*** (in Almaty, these are floodplain forests) consist of tree and shrub plants, which, due to the structure of the root system, are able to anchor the soil on the banks of a river. Such plants should be flood-resistant. Also, the biotope often includes aquatic and semiaquatic plants. More information about riparian biotopes can be found in *H. Riparian Forest Conservation and/or Restoration Tool*. The size of a biotope must exceed 0.5 ha. Size comes from the definition of a forest by the Food and Agriculture Organization (FAO) and the International Union for Conservation of Nature (IUCN 2008). Biotopes of the same type should be spatially connected to each other with corridors.

Figure 77. Bird box

Source: The Wildlife Community
https://thewildlifecommunity.co.uk/products/forest-bird-nestbox-and-feeder.

Figure 78. Bat box

Source: Big bat box
https://www.bigbatbox.com/blogs/learn/the-surprising-benefits-of-bat-boxes-and-why-you-should-have-one.

Figure 79. Insect hotel

Source: Woodland Trust
https://www.woodlandtrust.org.uk/blog/2019/09/how-to-build-a-bug-hotel/.

- **Create bird boxes.** These can be separate small boxes (birdhouses and tit houses, hollow houses for spruce owls, boxes for swifts) or cavities in buildings. Nest boxes should be installed at least 2–3 m above the ground (BTO 2010). In highly urbanized areas, they should be installed higher, at 4–5 m, so that birds can hide from city noise and other disturbance. For example, more than 50 percent of the nests of *Turdus merula* in Almaty are located higher than 4 m above the ground (Kovshar 1988). If there is an intent to attract specific bird species, an ornithologist should be consulted about the nest box height and diameter of the hole (Figure 77).[55]
- **Create the bat boxes.** Eight species of Chiroptera live in Almaty. They settle near water; they are affected by urbanization and landscape beautification, because they lose their homes—hollow trees and trees with dense crowns. In search of shelter they fly into houses, get into attics and inter-window spaces, and sometimes die there. To help them, consider creating special places for them to live and hibernate. These can be bat boxes and cavities in houses (Figure 78).[56]
- **Create insect hotels.** Build them to attract useful insects to the territory. These insect hotels are boxes or frames with compartments filled with different materials: natural (hollow stems of reeds, pine cones, dry leaves, bark, stones) or even construction debris. Different insects prefer different types of materials. The house should be created in a place protected from wind and rain, preferably far from places with many people, especially children (Figure 79).

Where? Suitability consideration

Geographic areas

Urban, rural

Spatial zones

Zone 3: Area between buffers

Technical specifications

Anthropogenic load: in areas without public access or away from actively used recreational paths and sites

Visualization of the *Terrestrial Biotopes Tool* in the Green Corridors context

Figure 80 shows the creation of a biotope in a low recreational zone with a diverse species composition and restricted human access when naturalizing the Malaya Almatinka riverbed between Bogdan Khmelnitsky Street and Bukhtarmirsky Street in the districts of Zhas Kanat, Mayak, and Abay Avenue.

[55] For more information about creating the bird boxes, see TheCornellLab of Ornithology website: *Features of a good birdhouse - Nestwatch*: https://nestwatch.org/learn/all-about-birdhouses/features-of-a-good-birdhouse.

[56] For an overview of building bat boxes, see the Bat Conservation Trust website. *Buildings, planning, and development - Bat Boxes*: https://www.bats.org.uk/our-work/buildings-planning-and-development/bat-boxes.

Figure 80. Forest biotope created in the riparian buffer of Malaya Almatinka River

Before - site of complete naturalization of the Malaya Almatinka channel, fragment with biotope location

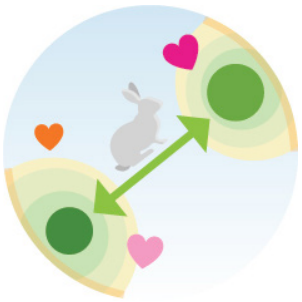
After - biotope, species diversity, increase in bird and animal species, restoration of the natural ecological system

Location: https://goo.gl/maps/rXHmob2LWKm3ErHm7.
Source: MLA+ graphics, Google images.

2.5. Green Linkages Approach

Objective

Create ecological and recreational connections between green corridors and urban natural areas. This makes it possible to reduce the fragmentation of the city's green network and create recreational links between parks and boulevards, so that any citizen can go for a walk in the shade of trees.



Slogan

"Create convenient green linkages for agglomeration residents and local biodiversity!"

Figure 81. Challenges mitigated by the Green Linkages Approach.

Challenges

Habitat fragmentation

Lack of accessibility of parks and nature

Loss of biodiversity

Source: MLA+.

Figure 82. Benefits of the Green Linkages Approach.

Benefits

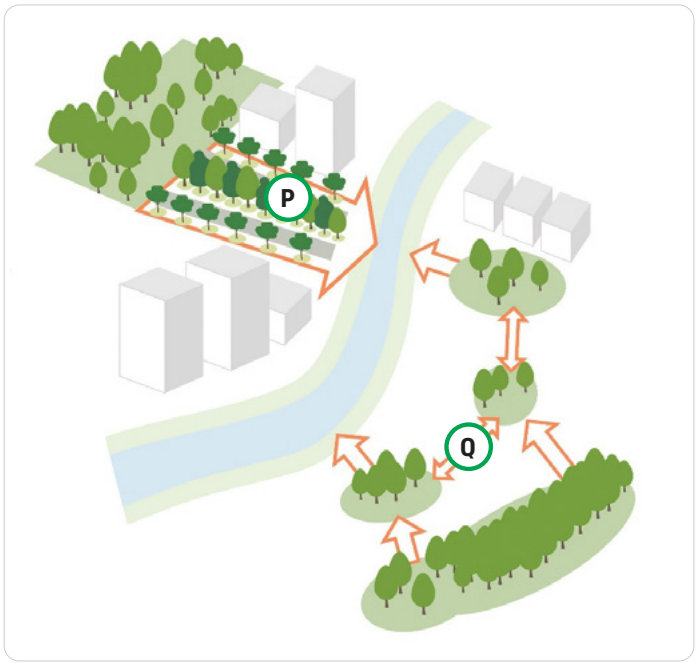
Habitat connectivity

Accessibility of parks and nature

Source: MLA+.

Illustration of tools for this approach

Figure 83. Tools for the Green Linkages Approach



P City boulevards

Q Stepping stones

Source: MLA+.

P City Boulevards

Description

This tool refers to creation of a wide strip of green space on either side of the roadway or in the middle (Figure 84). The tool aims to create ecological and recreational links between 'big' nature and urban green public spaces, providing residents with opportunities for walking and recreation. The *City Boulevards Tool* supports the *Green Linkages Approach*.

Figure 84. A good example of an urban boulevard: Bukhar Zhyrau Boulevard, 32 m long, connecting Satpayev Square and Esentai Embankment

Rehabilitate, Restore, Enhance
Integrate existing elements of green infrastructure into a connected system

Create
Create ecological and recreational linkages between green areas and green corridors

Source: Google Street View, Кайпо Мәжөн отырған жер and yandex.come/maps.

Co-benefits

- Boulevards provide opportunities for recreation and walking in the shade of trees between parks and embankments, promoting a healthy lifestyle.

What? How?

- **Analyze the ecological connectivity;** identify green 'areas' and corridors.
- **A 'good green link' should be of sufficient width and length depending on the conservation goal,**[57] with tiered and continuous green spaces.
- **The minimum width of tree cover is 30 m**[58] for bird, insect, and plant movement and good corridor function.
- **Select an assortment of trees in accordance with the TMP.**
- **Lighting should be directed downward** to avoid disturbing animals.

[57] As per USDA guidelines. See the official website - *Corridor Width:* https://www.fs.usda.gov/nac/buffers/guidelines/2_biodiversity/9.html.

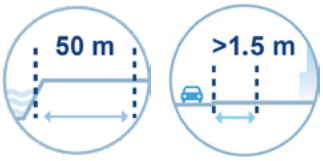
[58] As per USDA guidelines. See the official website - *Corridor Width:* https://www.fs.usda.gov/nac/buffers/guidelines/2_biodiversity/9.html.

- **Boulevards must have an entrance** (which includes basic infrastructure and a crosswalk) to natural areas and the waterfront, that is, lead 'from point A to point B'.
- **Recreational infrastructure should include** comfortable pedestrian paths with the possibility of a bicycle path and pedestrian crossings.

Where? Suitability consideration

Geographic areas
Urban

Spatial zones
Zone 2.2: Concrete bank river buffer
Zone 5.2: Road buffer_Street



Land use
Public areas: streets

Technical specifications
Dimensions: 30 m - optimal width of the green strip
Location: Boulevards are placed between the most valuable green 'areas' and the main green corridors.

Figure 85. Utepova Street boulevard

Before - Utepova Street, intermittent greening

After - Utepova Boulevard connects Botanical Garden and Bolshaya Almatinka

Visualization of the City Boulevards Tool in the Green Corridors context

Figure 85 shows Utepova Street between the Botanical Gardens and Bolshaya Almatinka that is to be transformed into a boulevard, filling in gaps in the landscape and providing additional recreational infrastructure.

Location: https://goo.gl/maps/75gZ4ZJVeAkA5aVM9.
Source: MLA+ graphics, Google images.

Q Stepping Stones

Description

This tool is used to create an ecological and recreational link between large green spaces in the form of a network of green spaces such as parks and public squares located near each other. (Figure 86). Such places are more commonly known as pocket parks (World Bank 2021a). Pocket parks are small green public spaces that increase residents' accessibility to green spaces and provide a wide range of recreational opportunities for neighborhood residents (children's and sports fields, dog walking areas, and so on).

The *Stepping Stones Tool* supports the *Green Linkages Approach*. This tool can be used in situations where it is not possible to directly connect green spaces to each other due to obstacles such as highways, large industrial areas, and dense urban environments with insufficient road widths.[59]

Figure 86. An example of a system of small squares, green spaces, and parks acting as a green link between two major green cores: Wanstead Flats and Olympic Park in the Lea Valley, London, England

Rehabilitate, Restore, Enhance
Integrate existing elements of green infrastructure into a connected system

Create
Create ecological and recreational linkages between green areas and green corridors

Source: MLA+, Google images.

Co-benefits

- Provides a corridor for urban animal and bird movement even though the green spaces are not directly connected (World Bank 2021a)
- Increases the accessibility of public green space within walking distance.

[59] As per USDA guidelines. See the official website - *Stepping stones and gaps:* https://www.fs.usda.gov/nac/buffers/guidelines/2_biodiversity/7.html.

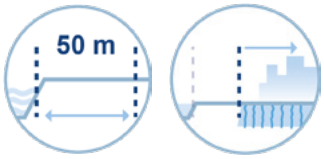
What? How?

- **Identify which green corridors and green 'areas' need to be connected.**
- **Identify suitable locations for green 'islands',** which could be unsplit land, wasteland, areas along the railway, deserted areas of small rivers, sections of wide roads, and so on, and turn them into parks and squares.
- **The shorter the distance between the green 'islands', the better.** The minimum distance between green 'islands' depends on the species of birds and animals that can migrate along the green connection.[60]
- **Fix the legal status of new parks** in spatial planning documents.

Where? Suitability consideration

Geographic areas
Urban

Spatial zones
Zone 2.2: Concrete bank river buffer
Zone 3: Area between buffers



Technical specifications
Dimensions: Green areas should be close to each other.
Location: Stepping stones are placed between the most valuable green 'areas' and the main green corridors.

Visualization of the *Stepping Stones Tool* in the Green Corridors context

Figure 87 shows the park system between Baum Grove (Roscha Bauma) and the Malaya Almatinka river valley, preserving and giving status to small riverbeds.

Figure 87. The park system between Baum Grove and the Malaya Almatinka river valley

Before - abandoned small riverbeds between Roscha Baum and Malaya Almatinka river

After - a system of public gardens linking the Baum Grove and Malaya Almatinka

Location: https://goo.gl/maps/2F854RyZ89dHmUVn6
Source: MLA+ graphics, Google images.

[60] As per USDA guidelines. See the official website - *Stepping stones and gaps:* https://www.fs.usda.gov/nac/buffers/guidelines/2_biodiversity/7.html.

2.6. Recreation Development Approach

Objective

Create continuous recreational paths in the shade of trees and opportunities for comfortable nature recreation, including rest areas.

Slogan

“Ride from Medeu to Konaev without getting off the bike.”

Figure 88. Challenges mitigated by the Recreation Development Approach

Challenges

Lack of infrastructure for recreation

Lack of accessibility of parks and nature

Negative impact of climate change on human health

Source: MLA+.

Figure 89. Benefits of the Recreation Development Approach

Benefits

High-quality environment for recreation

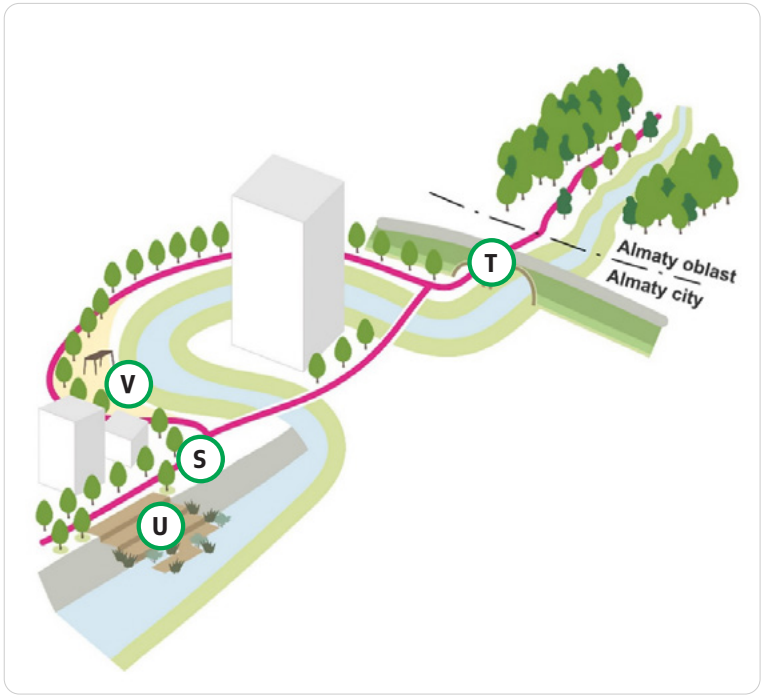
Tourist attractiveness

Improving the health of the population

Source: MLA+.

Illustration of tools for this approach

Figure 90. Tools for the Recreation Development Approach



S Recreational route along rivers

T Intersection of the route with a street

U Water’s edge access

V Picnic zones, rest zones

Source: MLA+.

S Recreational Route

Description

This tool is focused on creating continuous landscaped paths in the shade of trees along major rivers. The tool is designed to provide convenient access for local residents to riverbanks for hiking, biking, sports, and outdoor recreation (Figure 91). The *Recreational Route Tool* supports the *Recreation Development Approach*.

Figure 91. A good example: the outdoor training paths on Malaya Almatinka

Create
Create continuous landscaped paths in the shade of trees

Source: https://kaztag.info/ru/news/rekonstruktsiyu-na-terrenkure-planiruyut-nachat-v-nachale-leta-v-almaty?.

Co-benefits

- **Increased physical activity levels.** Safe and comfortable routes for walking, running, and cycling, encouraging people to spend more time outdoors and increasing physical activity levels.
- **Development of a cycling culture.** The creation of recreational routes encourages the use of bicycles in the urban environment, promoting a cycling culture and offering an alternative and environmentally friendly way of traveling.
- **Tourism potential.** Beautiful views along the routes and a pleasant atmosphere can attract tourists, creating potential opportunities for the development of local businesses and the tourism sector.
- **Protection of small river valleys.** An embankment and bicycle route can form a clear boundary between the open natural landscapes of the green corridor and areas in the city, in suburban villages, and in new development areas. The presence of a clear boundary will block possible 'squatting' on the riverbanks.

What? How?

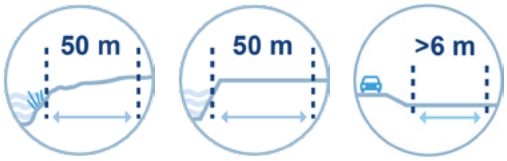
- **Within the boundaries of the city of Almaty:**
  - ***The minimum width of the path should be 2.5 m*** (WHO 2013). Where possible and consistent with design solutions, bicycle lanes should be added, physically or in a pavement separated from the main pedestrian path for the safety of citizens. In such cases, the width of the route will be no less than 6 m; also, the pedestrian flow in the area and activity of adjacent areas should be considered and the width of the path should be increased there.
  - ***The route should have stops and recreational areas with benches, sports, and play spaces*** depending on the activity on the promenade and the functional zoning and areas of the city.
  - ***The route should be shaded by tree crowns and landscaped*** to improve microclimate, air quality, and so on.

- **In the suburban area ('Oblast' of Almaty):**
  - ***The bicycle lane should be 3 to 3.5 m wide*** (WHO 2013). The bicycle route should be equipped with navigation support such as signboards.
  - ***The bicycle routes in the suburban area should be connected to the city's embankments,*** so that any citizen could leave his/her house and follow the green boulevards (see P. City Boulevards Tool) to the river and go for a bicycle ride along the embankments.
  - ***Routes should be looped with other paths,*** if possible, to have different views and create small rings of varying levels of difficulty for 2 to 4 hours of activity.
  - ***Rest areas should be located approximately every 5 km*** (with the exact spacing distances to be specified according to each project, see V. Rest Areas along the Recreational Route Tool). They should preferably be next to the existing settlements or future development areas, if such are available on the route. The recreation area consists of a shelter, benches, litter garbage cans, and infrastructure for maintenance of bicycles. Also, the recreation area may include a sales point (kiosk) for the sale of products of local farmers (or adjacent to the existing retail outlet). Organization of recreation areas is recommended to implement in partnership with the producers of local products.
  - ***Creation of additional tourist infrastructure along the route —*** campsites, glamping sites, recreation centers, sports, and recreational activities — is welcome.

Where? Suitability consideration

Geographic areas
Urban, rural

Spatial zones
Zone 2.1: Natural riverbed buffer
(50 m from water edge) - priority zone
Zone 2.2: Concrete bank river buffer
(50 m from water edge) - priority zone
Zone 5.1: Road buffer_Highway

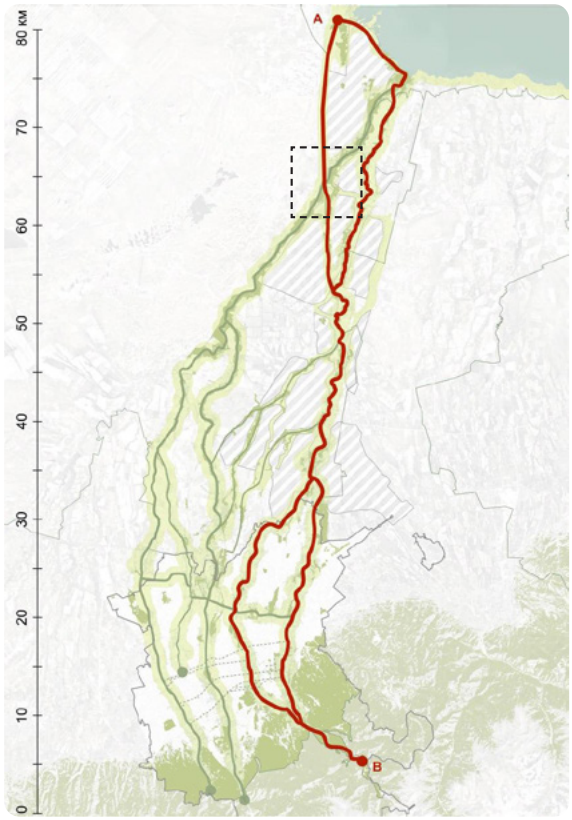


Technical specifications
Dimensions: The width of the lane should be between 2.5 and 3.5 m (WHO 2013)

Visualization of the *Recreational Route Tool* in the Green Corridors context

Figure 92 shows a fragment of the route Katok Medeu–Konaev 'From the mountains to the Kapchagai Reservoir' along the Malaya Almatinka and Esentai rivers. The length of the route is 203 km.

Figure 92. 'Katok Medeu–Konaev' route map



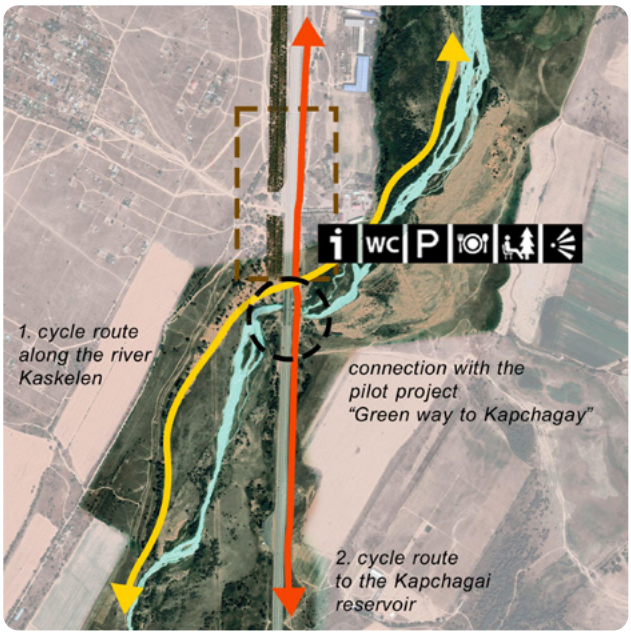
Source: MLA+

Figure 93 shows a fragment of the connection of the bicycle path 'Katok Medeu–Konaev' to the pilot project 'Greenway to Konaev'. The route continues along the Kaskelen river to the Kapchagai Reservoir.

Figure 93. Fragment of the connection of the bicycle path 'Katok Medeu-Konaev' to the pilot project 'Greenway to Kapchagai'

Before - Kaskelen Valley

After - a bicycle path along the Malaya Almatinka branch of the Green Corridor, connects to the pilot project and continues along the Kaskelen river to the Kapchagai Reservoir



Location: https://goo.gl/maps/TYrRestirAgoQJdv7.
Source: MLA+ graphics, Google images.

T Intersection of the Route With a Street

Description

This tool is intended to provide a comfortable way to travel along trails without having to climb stairs or cross multiple levels, for example, by creating cycle-pedestrian passages under or over bridges and city streets, as well as ramps for a smooth transition from one embankment level to another when approaching crosswalks (Figure 94). The Intersection of the *Route With a Street Tool* supports the *Recreation Development Approach.*

Figure 94. Tunnel under the street for the bicycle path, a fragment of the 60-meter tunnel for the RijnWaalpad recreational path, The Netherlands

Protect
Create a safe barrier-free environment for low-mobility groups of population

Create
Create a convenient intersection between the recreational route and streets

Source: Interreg, Bicycle tunnels on RijnWaalpad cycle highway, 2017, https://www.nweurope.eu/projects/project-search/cycle-highways-innovation-for-smarter-people-transport-and-spatial-planning/news/bicycle-tunnels-on-rijnwaalpad-cycle-highway/.

Co-benefits

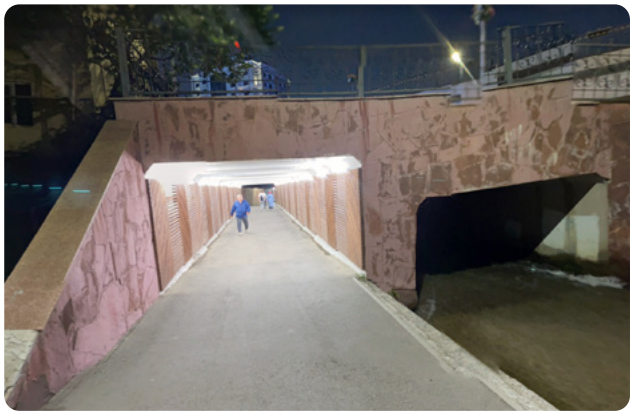
- **Gentle, multilevel crossings should minimize the number of forced stops along recreational routes within the green corridor.** Currently, continuous and convenient movement of pedestrians and cyclists along the rivers in the central part of the city is difficult because of the undeveloped junctions with the city's main roads. Comfortable intersections will improve the quality of the recreational route, which is largely determined by the number of obstacles users overcome that force them to stop, wait, or climb stairs.
- **Creating intersections with routes will increase their inclusiveness and accessibility for less mobile populations.** Stairs between different levels of the promenade are the most tangible obstacles, especially for people with children and those with reduced mobility.

What? How?

- **Study the conditions.** First, the water balance should be studied—how much the water level rises in different seasons and how the river behaves during floods. Next, a study of the engineering structures should be carried out to determine the best possible method of intervention.
- **Create a pedestrian tunnel/overpass in bridge structure.** Ensure that the height of the bridge structure allows a person to pass, taking into account the girder (Figure 95). In some cases, it may be possible to lower the level of the embankment.
- **Construct the embankment deck on piles or pontoons.** The level of the embankment is lowered below the bridge (Figure 96).

- **Construct a ramp between the lower level of the embankment and the area in front of the pedestrian crossing:**[61]
  - The slope of the ramp must not exceed 5 percent, with the maximum cross slope 20 percent.
  - The width of the ramp should be at least 1.5 m (for one-way traffic) or 2.5 m (for two-way traffic). This allows wheelchair users and people with reduced mobility to maneuver freely and ensures the safety of pedestrians and other road users.
  - Ramps should have a smooth transition to pavement and road level to avoid sudden changes in height.
  - Tactile tiles should be installed on ramps for visually impaired people to help them navigate the site.

Figure 95. Good example: The intersection of the Small Almatinka Terrenekur and Al-Farabi Avenue



Source: Daulet Yerkinov, https://maps.app.goo.gl/hpLGiyeuFLhnWZ348.

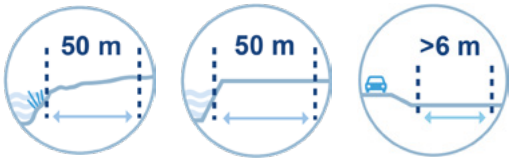
Figure 96. Good example: Terrenekur crossing on the Esentai river with an engineering structure

Photo Credit: Viktor Korotych.

Where? Suitability consideration

Geographic areas
Urban, rural

Spatial zones
Zone 2.1: Natural riverbed buffer (50 m from water edge)
Zone 2.2: Concrete bank river buffer (50 m from water edge)
Zone 5.1: Road buffer_Highway



Technical specifications
Location: The intersection of a transport and/or engineering infrastructure road and a recreational route where it is difficult to pass/run or the route passes under a bridge.
Dimensions: The distance from the surface of the walkway to the bottom of the bridge structure shall be at least 3 m to allow passage underneath, taking into account the engineering of the crossing. If it is not possible to pass under the bridge, ramps and slopes should be provided.

[61] The norms were taken from SP 59.13330.2020. 2021. *Accessibility of buildings and facilities for low mobility groups of population*: https://docs.cntd.ru/document/573659328.

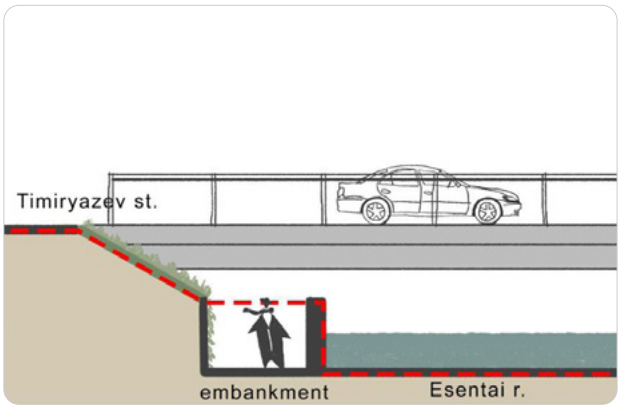
Visualization of the Intersection of the *Route With a Street Tool* in the Green Corridors context

Figure 97 and Figure 98 show the lowering of the embankment level and creation of a continuous path along the Esentai under the Timiryazeva Street bridge structure.

Figure 97. Creation of a path along Esentai under the bridge structure on Timiryazev Street

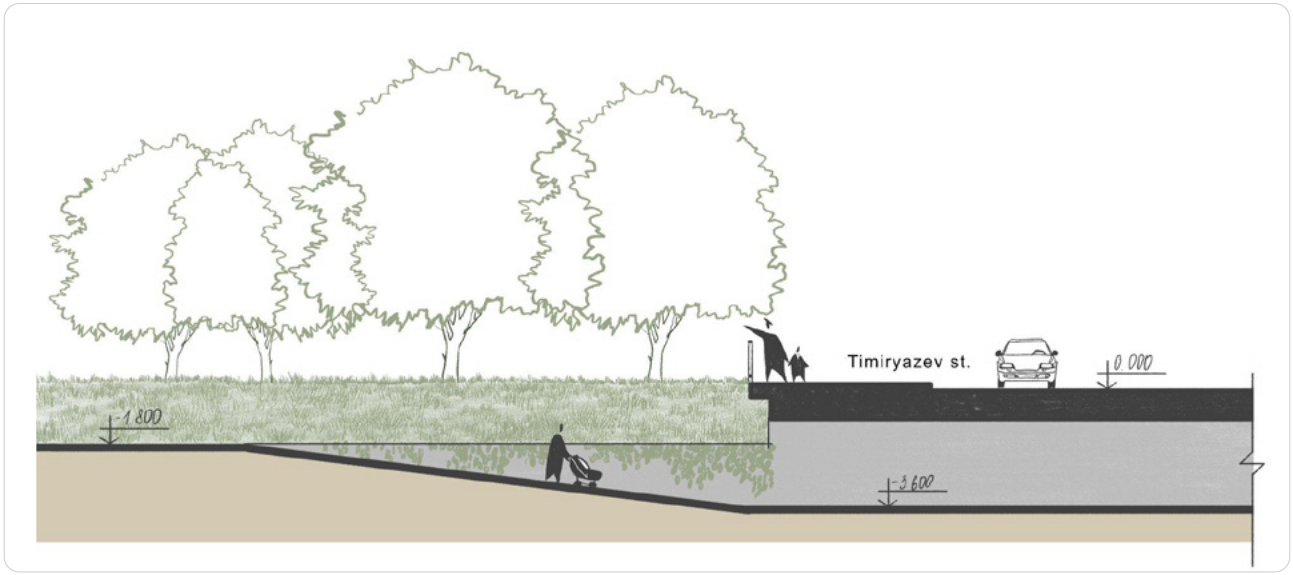
Before - the Esentai embankment juts into the street with no crossing and no option to climb up the pavement. Intersection of Esentai and Timiryazev Street

After - passage under the bridge; a continuous path along the water including for people with limited mobility



Location: https://goo.gl/maps/AWrtZkiYz3Nsqn5v8.
Source: MLA+ graphics and photo, Google images.

Figure 98. Construction of smooth lowering of embankment level; minimum height from pavement floor to top of bridge structure - 2.5 m; vertical wall landscaping



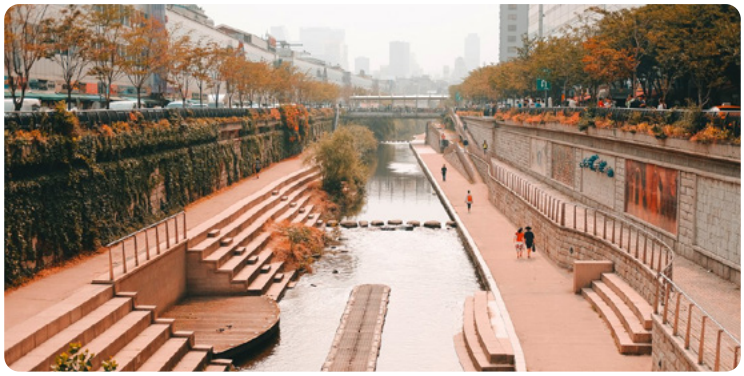
Source: MLA+.

U Water Edge Access

Description

This tool is designed to provide comfortable water contact and recreation opportunities. Access can be provided by creating a ladder or a pontoon (Figure 99). The *Water Edge Access Tool* supports the *Recreation Development Approach.*

Figure 99. Steps to the water can be formed either through reconstruction of the bank slope (left bank) or attached to the structure (right bank), Cheonggyecheon Canal, Seoul



Create
Create water access and public spaces on the water

Source: Tripadvisor, https://www.tripadvisor.com/Tourism-g294197-Seoul-Vacations.html.

Co-benefits

- **Being one with nature.** Contemplating the sights and sounds of the water helps relieve stress and tension.
- **Sheltered from the noise of the street, places for socializing are created.** Located below the main promenade, the descent to the water becomes a new kind of public space.
- **Allowing to organize sports and recreational activities on the surface of waters** and watercourses (in places where it is safe to do so). Such activities may include sailing, kayaking, boating, catamaran trips, and fishing.

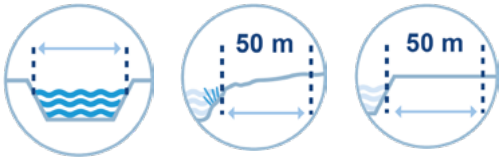
What? How?

- **Organize concrete steps to the water in a regulated channel.** They can be submerged during floods.
- **Create wooden decks, steps to the water, or a rock outline on natural banks.** Make sure that the landscaping does not interfere with the functioning of the river ecosystem.
- **Establish a system to inform the public of rising water levels** and the potential danger of using the descents.

Where? Suitability consideration

Geographic areas
Urban

Spatial zones
Zone 1: waterway
Zone 2.1: natural riverbed buffer (50 m)
Zone 2.2: concrete bank river buffer (50 m)



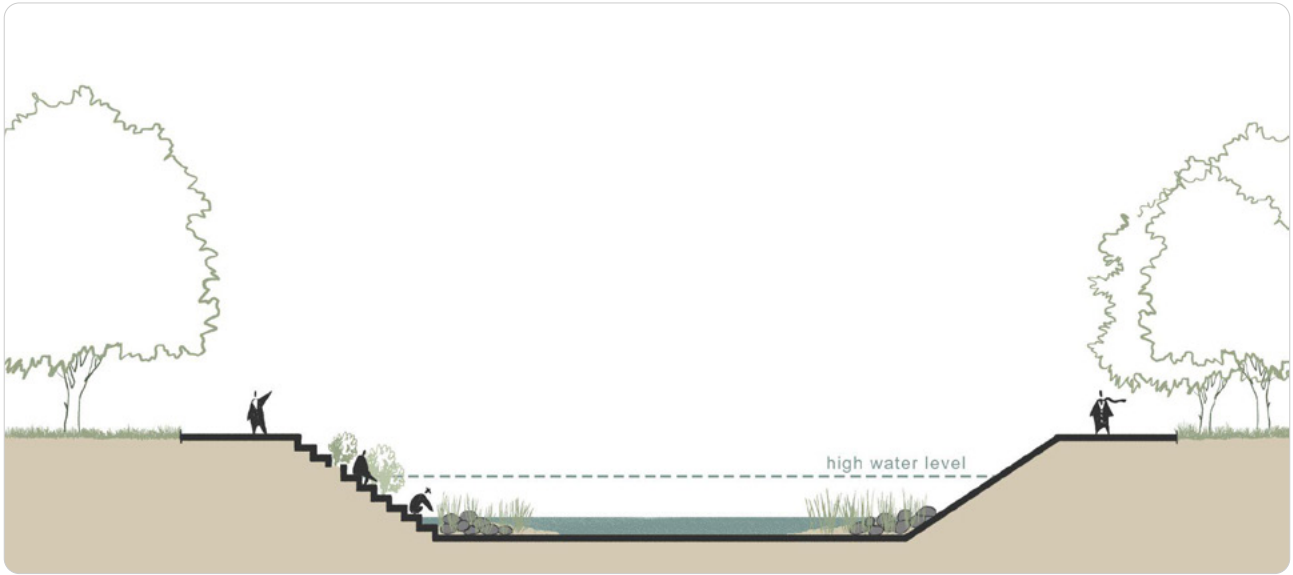
Technical specifications
Location: adjacent to a recreational route, near recreational and sporting zones
Flood risk: low mudflow hazard.

Visualization of the *Water Edge Access Tool* in the Green Corridors context

Figure 100 and Figure 101 show the construction of a slope on Bolshaya Almatinka between Abay Ave. and Sairan Lake, with an amphitheater and steps for seating. During the seasonal floods, the water covers the concrete steps without damaging the pavement.

Figure 100. Before - water access is closed

Figure 101. Post-conversion of part of the concrete slope on the Bolshaya Almatinka into a slope to the water with additional landscaping of the steps—if possible, retaining the shoals with the addition of riprap and aquatic vegetation



Location: https://goo.gl/maps/yHHUqXUtue78PvQS6.
Source: MLA+ graphics, Google images.

V Rest Areas along the Recreational Route

Description

The tool suggests creating a system of specially equipped places for outdoor leisure near recreational routes along green corridors. It can be organized both in the city and in the countryside on the banks of lakes, rivers, or other natural places (Figure 102). The Rest Areas along the *Recreational Route Tool* supports the *Recreation Development Approach*.

Figure 102. Good example of picnic area near the Prohodnaya river, Qalalyq Ferma, Almaty, Kazakhstan

Create
Create systems of rest stops along the recreational route

Source: https://visitalmaty.kz/eda/qalalyq-ferma/.

Co-benefits

- Providing opportunities for recreation, sports, and communication
- Increasing comfort through the possibility to use basic infrastructure (toilets, cafes, and so on)
- Enhancing the tourist attractiveness of the recreational route, for example, by organizing viewpoints.

What? How?

- ***Short-term rest zones:*** a point feature (approximately 4 x 4 m) whose function and content are directly dependent on the types of routes and the adjacent landscapes and features. It can be a crossing point, an information or viewpoint, or a resting point on a long stretch of path. These rest zones should be placed every 0.5–1.0 km (WHO 2013).

Possible variants of typical solutions:

- ***Entrance area or fork in the route:*** a small area including information blocks and a resting place. Separators are placed at the intersection of different types of routes, with several ways of applying to cyclists (City of Brampton 2019): either restricting the use of eco paths for extreme riding or reducing speed and more careful crossing of routes with a mixed flow of visitors (Figure 103 a).
- ***Viewpoint or landmark:*** a rest stop at a scenic, interesting, or significant site, with an information board and an art object. In addition, the place should be fenced off with cobbles or logs if by leaving the site one can trample or damage valuable ground cover or the forest or disturb its inhabitants (Figure 103 b).
- ***Sitting zone:*** an area with conventional dimensions, with a simple setup in the form of a bench and natural elements used as a visual marker (Figure 103 c).

Figure 103. Types of short-term rest areas

a. Entrance area or fork in the route b. Viewpoint or landmark c. Sitting zone

Source: MLA+ graphics.

- **Long-term rest zones:** plots of approximately 10 x 20 m; can include sports and entertainment functions and can be infrastructure nodes. They should be placed every 1.5–2.0 km (City of Brampton 2019).

Possible variants of typical solutions:

- **Basic infrastructure rest stops:** can act as an entrance area or be located at the intersection of routes, for example, toilets, catering facilities, resting places, information boards, parking (Figure 104).

Figure 104. Example of a rest stop with basic infrastructure

Source: MLA+ graphics.

- ***Picnic areas:*** should be placed in hidden areas away from the main recreational route (Figure 105). The surface on the site should be as natural as possible, in the form of soft forest flooring with sand added. Water, fire extinguishers, or sand boxes should be available near the public grills to prevent and control possible ignition.

Figure 105. Example of a picnic area

Source: MLA+ graphics, Keystone Terrain Park, USA https://live.staticflickr.com/4167/33979580944_d82197241d_b.jpg.

- ***Playground:*** playground equipment made of natural materials is preferable. Mulch, as a natural and water-permeable material, can be used as a covering. Sand is poured into the active play area for to make the surface softer (Figure 106). Low-growing dense shrubs are planted along the perimeter as a border between the playground and the wooded area (City of Brampton 2019).

Figure 106. Example of a playground rest stop

Source: MLA+ graphics; Regenstein Learning Campus at the Chicago Botanic Garden, USA https://landezine-award.com/regenstein-learning-campus/.

- ***Sports ground:*** an area of at least 15 m². The equipment should be accessible to all age groups and people with disabilities (City of Brampton 2019). The area can be equipped with tourniquets, bars, buffet walls, and various types of outdoor fitness equipment. A rubber shock-absorbing surface can be laid on the flat surface of the playground. On the relief surface of the sports ground, various elements for overcoming obstacles, structures made of logs, boards, and ropes can be arranged without affecting the existing trees (Figure 107).

Figure 107. Example of a sports ground rest stop

Source: MLA+ graphics; Parc Jardin des Sources, Quebec, Canada
https://i.pinimg.com/originals/d6/9f/a2/d69fa269c701c604e24402ae4e49426a.jpg.

- ***Dog grounds:*** an area of 250–400 m² with equipment for training dogs. The height of the equipment should not exceed 1 m for the safety of the pets. Forest flooring can be used to cover the main part of the site (Figure 108). Also, the site should have a safety vestibule to release and leash dogs at the entrance and exit and a signboard indicating a dog walking area (City of Brampton 2019).

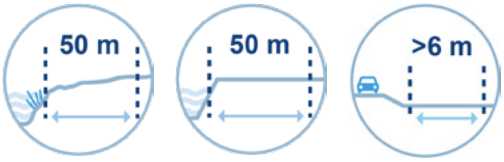
Figure 108. Example of a dog ground

Source: MLA+ graphics; Dog playground in Comi Republic, Russia
https://avatars.mds.yandex.net/get-ydo/4362967/2a0000017cd809f24b2b93de2814ff7ba015/diploma.

Where? Suitability consideration

Geographic areas
Urban, rural

Spatial zones
Zone 2.1: Natural riverbed buffer (50 m)
Zone 2.2: Concrete bank river buffer (50 m)
Zone 5.1: Road buffer_highway



Technical specifications
Location: adjacent to a recreational route, near recreational and sporting zones

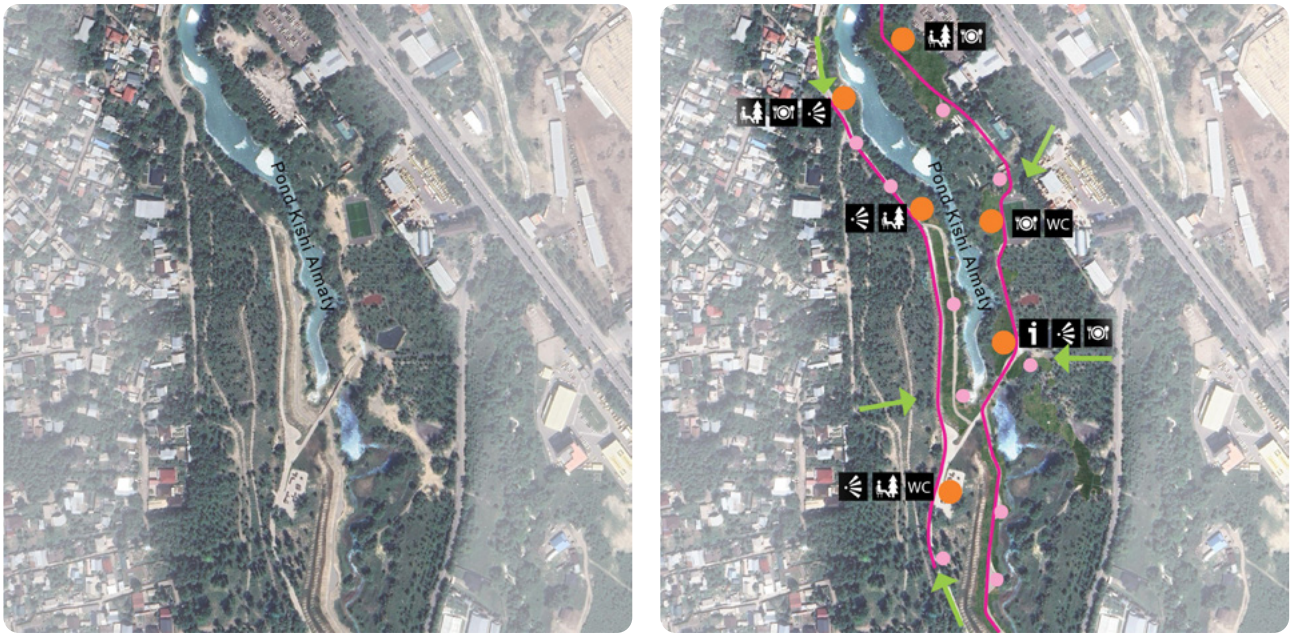
Visualization of the *Rest Areas along the Recreational Route Tool* in the Green Corridors context

Rest areas of different use are represented as a working system along the recreational route next to Pond Kishi Almaty (Figure 109).

Figure 109. Rest areas along the recreational route

Before - Pond Kishi Almaty without recreation

After - recreational activities and rest areas at Pond Kishi Almaty



Location: https://maps.app.goo.gl/ysHCVYUN9DmhWTRVA.
Source: MLA+.

2.7. Harvesting of Additional Water Resources Approach

Objective

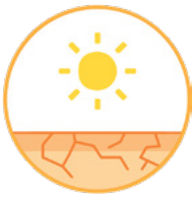
Harvest rainwater from roofs to store it and use for irrigation purposes and in new landscaping projects.

Slogan

"Water the green corridor vegetation primarily from local sources."

Figure 110. Challenges mitigated by the Harvesting of Additional Water Resources Approach

Challenges



Drought, lack of water for irrigation

Flooding

Source: MLA+.

Figure 111. Benefits of the Harvesting Additional Water Resources Approach

Benefits

Water for irrigation

Saving fresh water and budget

Improving the microclimate in the city

Source: MLA+.

Illustration of tools for this approach

Figure 112. Tools for the Harvesting of Additional Water Resources Approach

W Closed rainwater harvesting system

X Open reservoir for water storage

Source: MLA+.

W Closed Rainwater Harvesting System

Description

The tool is intended to collect runoff from roofs into above-ground or underground tanks. The *Closed Rainwater Harvesting System Tool* supports the *Harvesting Additional Water Resources Approach*. The tool is designed to provide additional water for plant irrigation and other needs as well as reduce the load on the city's stormwater systems (Figure 113). Attenuation storage tank is an above- or below-ground void space for temporary storage of surface water before infiltration, controlled release, or use (Woods et al. 2015).

Figure 113. Rainwater harvesting from the roof through a filter into an underground tank

Create
Create systems of rest stops along the recreational route

Source: FarmLand rainwater harvesting system https://www.indiamart.com/proddetail/rainwater-harvesting-filter-fl-80-with-10-year-warranty-22733337388.html.

Co-benefits

- **Prevention of water evaporation;** longer storage capability
- **Protection of collected rainwater from pollution** and organizing of a water treatment system for its use (Woods et al. 2015).
- **Less susceptible to air temperature fluctuations** (Woods et al. 2015).

What? How?

- **Collect the water**
  - **Check the quality of collected water,** for example, surface runoff from a roof whose materials contain copper or zinc or have been coated with fungicides and herbicides may not be suitable for irrigation. In this case, filters should be provided (Woods et al. 2015).
  - **Choose a suitable rainwater harvesting system.** It depends on the volume of runoff, the characteristics of the area, the necessary access to the tank, and the quality of the water to be collected. They can be conditionally classified into two types: gravity system and pumping system:
    - ***Gravity system:*** Rainwater is collected by the force of gravity and stored in the tank at a level so that it can be used gravitationally. Accordingly, if it is planned to use water for domestic purposes in buildings, the tank is located on the roof or attic. It is necessary to consider the structural characteristics of the building. For irrigation, water is collected in an above-ground tank—a barrel. Advantages of the system: it is economical. Disadvantages: small collection volume and lack of control over the temperature and quality of water (Woods et al. 2015).

- ***Pumping system:*** Rainwater is collected from the roof in an underground tank and delivered to the place of use with the help of a pump; filters can be added. Advantages of the system: temperature control, bacterial reduction, frost protection, large volumes of water storage, valuable above-ground space saving. Disadvantages: need for excavation, need for a pump, and greater contribution to maintenance (Woods et al. 2015).

- **Store and use water.**

  Tanks are connected to the systems of rainwater harvesting—underground tanks can be on the house plots, under public squares, under parking lots, or under the flat sports fields. Tanks are used in areas where it is not planned to plant trees or without existing trees (Woods et al. 2015).

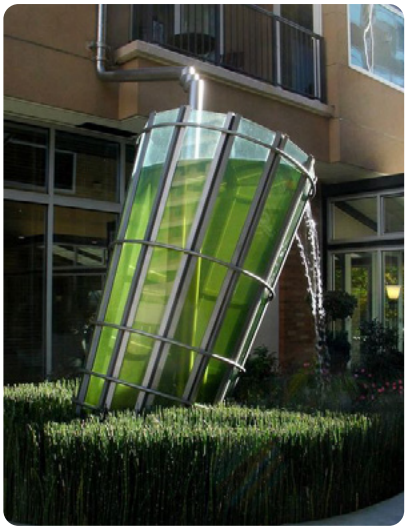
Figure 114. A barrel for small storage capacity

Source: https://www.urbangreenblue-grids.com/measures/rainwater/.

Figure 115. Cisterns for bigger storage capacity

Source: https://www.greywatercorps.com/rainwater.

Figure 116. Water storage as an element of public space



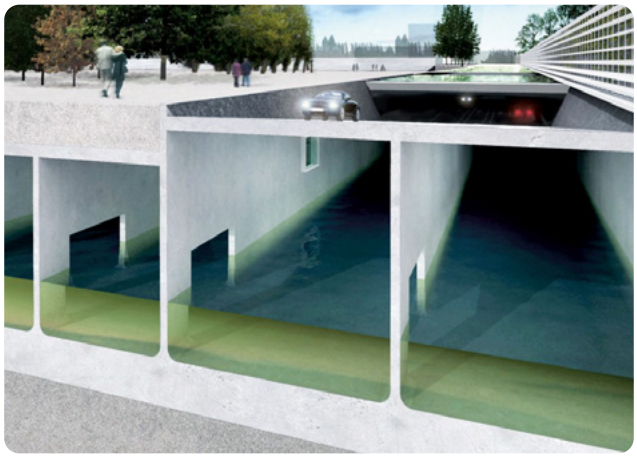
Source: Water table Buster Simpson

- ***Above-ground storage tank:*** barrels (Figure 114) and cisterns (Figure 115): small volumes, easy access to resources. Such tanks occupy a valuable ground area. They can be utilitarian or have an aesthetic, eye-catching appearance (Figure 116).
- ***Underground storage tanks*** (preferably used for watering plants because of controlled water quality): big storage capacities, excavation work required, temperature control (frost/sun), filters can additionally be installed, does not take up valuable above-ground area, installed underground on open surfaces without trees. The storage structure is usually formed using one of the following methods: geocellular storage systems (Figure 119), plastic tanks (Figure 117), plastic corrugated arch structures, oversize concrete and plastic pipes, corrugated steel pipes, precast or in situ concrete box culvert sections and tanks (Figure 118), glass-reinforced plastic (GRP) tanks, hybrid structures using reinforced earth walls and concrete roof panels (Woods et al. 2015).

Figure 117. Underground closed plastic tank

Source: https://dunhamengineering.com/underground-water-storage-tanks-learn-the-pros-and-cons/.

Figure 118. Storage system under buildings, for example, under an underground parking garage



Source: https://www.urbangreenbluegrids.com/measures/rainwater-storage-below-buildings-such-as-parking-garages/.

Figure 119. Underground storage tank made of geocellular storage system - constructed below the sport field does not take valuable land, store rainwater from roofs and surface water runoff, which mitigates flooding

Source: https://www.urbangreenbluegrids.com/measures/infiltration-boxes-and-infiltration-drainswells/rainwater-storage-beneath-sports-fields/.

Where? Suitability consideration

Geographic areas
Urban, rural

Spatial zones
Zone 3: Area between buffers

Technical specifications
Unique features: Priority should be given to collecting water from green roofs (Woods et al. 2015). Integrated rainwater harvesting and utilization should be introduced in new construction, as it is not economically feasible to reconstruct existing buildings.

Visualization of the *Closed Rainwater Harvesting System Tool* in the Green Corridors context

Figure 120 shows the gravity water intake system for collecting water for local irrigation, and Figure 121 shows the pumping rainwater harvesting system from the roofs of buildings and structures with above-ground and underground types of tanks.

Figure 120. Gravity water intake system for collecting small amounts of water for local irrigation

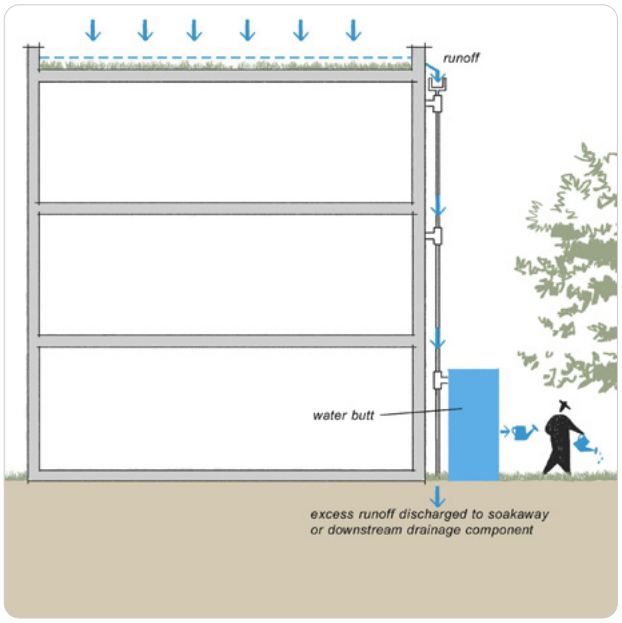
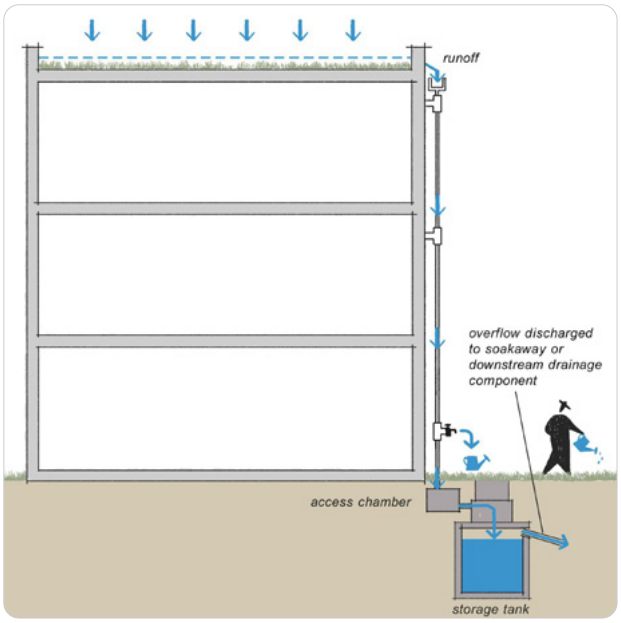


Figure 121. Pumping rainwater harvesting system into an underground tank



Location: https://goo.gl/maps/yHHUqXUtue78PvQS6.
Source: MLA+ graphics.

X Open Reservoir for Water Storage

Description

The tool (artificial pond) refers to the creation of a depression to temporarily store surface water above ground and rainwater while biologically removing pollutants (Woods et al. 2015) (Figure 122). The tool is designed to obtain additional water for watering plants, improving the microclimate of the city, and creating pleasant spaces for recreation and other needs. The *Open Reservoir for Water Storage Tool* supports the *Harvesting Additional Water Resources Approach*.

Figure 122. Example of water square, a pond connected to rainwater harvesting systems, Potsdamer Platz, Berlin, Germany

Protect
Microclimate improvement, water purification

Create
Create systems to collect and store water

Source: Photo Atelier Dreiseitl, https://www.urbangreenbluegrids.com/projects/potsdamer-platz-berlin-germany/.

Co-benefits

- **Draining water** from underground reservoirs during extreme peak flows.
- **Microclimate improvement:** lowers air temperature in summer, binds dust particles, and moisturizes the air.
- **Purification of the water** through the process of phytoremediation (Reichenauer and Germida 2008).
- **Increased biodiversity** as the pond is home to birds and animals, and an open reservoir can act as a rain garden.

What? How?

- **Create a natural filter system — biotope with vegetation.** Rainwater from the roofs of surrounding buildings is collected in underground tanks and then, passing through the biotope and being purified, flows into the pond. If necessary, filter engineering systems can be added during the summer months to clean the water from algae and blooms;
  - ***Disadvantages of using ponds:*** no control over temperature and water quality — frost, sun, bacteria; requires maintenance — clogged with leaves, debris, dirt, and so on (Woods et al. 2015).

Where? Suitability consideration

Geographic areas
Urban, rural

Spatial zones
Zone 3: Area between buffers

Technical specifications
Dimensions: The size of the tank depends on the calculation of the amount of water to be taken in.
Location: The open reservoir must be connected to a water collection system.

Visualization of the *Open Reservoir for Water Storage Tool* in the Green Corridors context

Figure 123 shows placement of a pond and an open reservoir for rainwater storage at the Auezov Theatre Square. A natural water body increases the area of the park and creates an oasis in the center of Almaty. This area becomes a full-fledged case study for the application of water and green infrastructure in the city within the green corridor.

Figure 123. Open reservoir for rainwater storage at the Auezov Theatre Square

Before - concreted square in front of the Auezov Theatre

After - an area with an integrated natural pond and an open storage tank into which run-off from the theater roof is collected and filtered by vegetation. Part of the water is redirected to the fountain system in the square.

Location: https://goo.gl/maps/VhxjVRhWbdT64rmV6.
Source: MLA+ graphics, Google images.

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Annex 1. Analytical Assessments

Analytical assessments can help the user take the first step in creating a vision of green corridors interconnected into a greater green network, understanding the initial context of a territory, and gathering information to decide on appropriate approaches and tools described in this report. Provided assessments can be used as examples for Akimat to create terms of reference for future green projects or by professionals for inspiration.

The analytical assessments in this annex were conducted to establish the vision of Green Network for Almaty Agglomeration (follow 1.2 *Overview of suggested Green Network for Almaty Agglomeration Section*). The annex consists of the following sections: *Area Selection for a Green Network; Understanding the Landscape; Asset Assessment.*

A1.1. Area Selection for a Green Network

Area selection assessment is used to designate a study territory for a green network.

The boundary for consideration of the green network for Almaty Agglomeration was determined primarily on the geographical basis, including landscape features such as river valleys from the source to the mouth of the river. The various discussions with Akimat of Almaty and Akimat of Almaty Oblast and different stakeholders of the initiative influenced the final boundary determination. The area for a green network includes the territory of Almaty City, as well as parts of Iliyskiy and Talgar districts and Konaev City in Almaty Oblast (Figure A1.1).

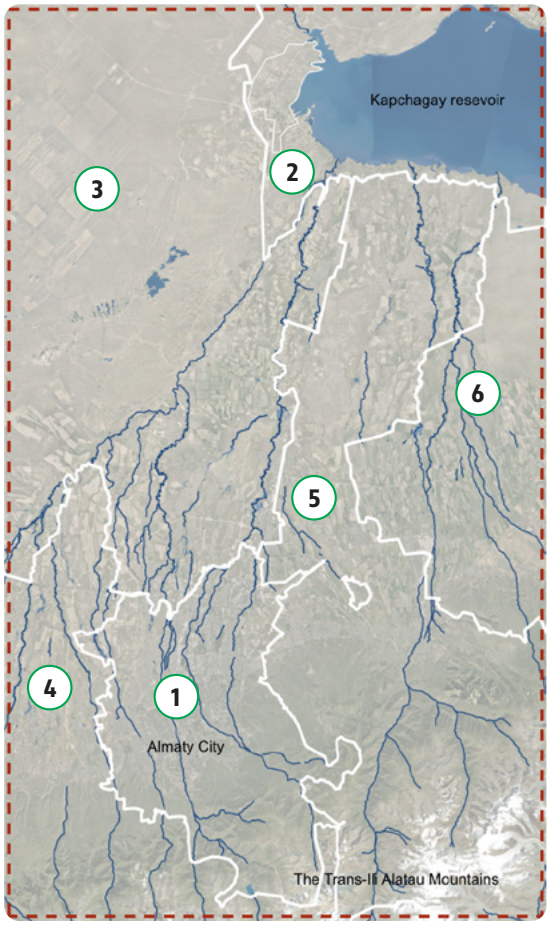


Figure A1.1. The consideration area of Almaty Agglomeration green network

1. Almaty City

Almaty Oblast:

2. Konaev City
3. Iliyskiy District
4. Karasay District
5. Talgar District
6. Enbekshikazakh District

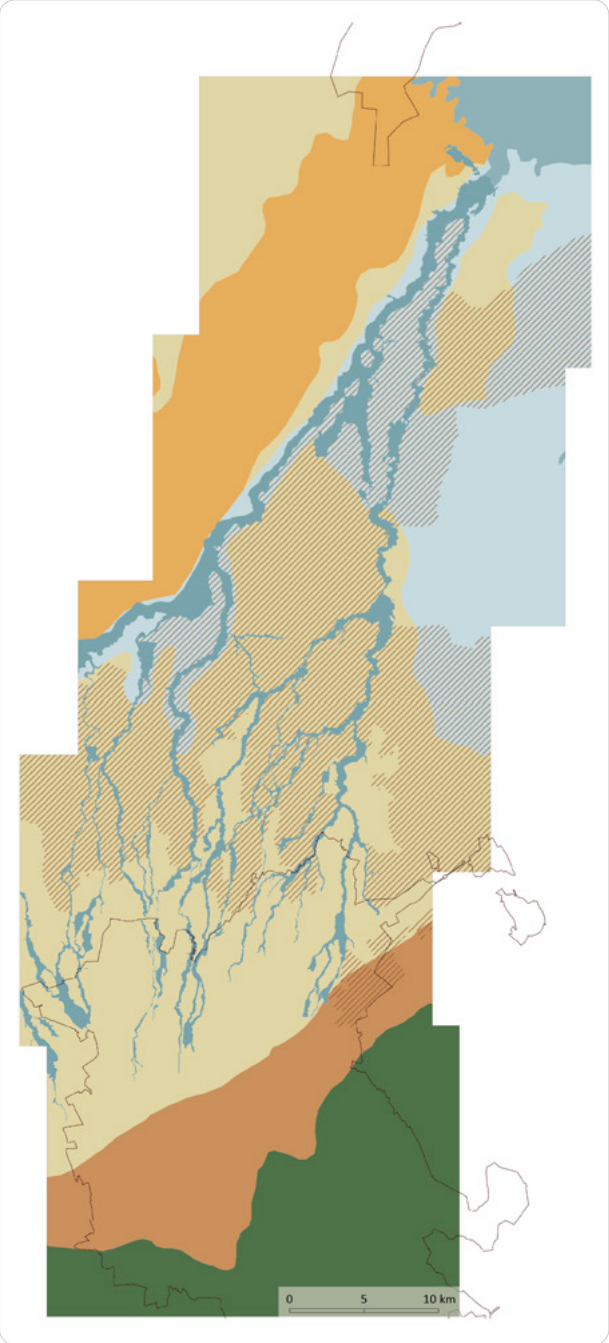
Source: MLA+.

A1.2. Understanding the Landscape

Landscape assessment is used to study land mosaics, including patches, corridors, and matrix (Dramstad, Olson, and Forman 1996), to understand which landscapes will form a green network; determine landscape zones which are present in the area to choose planting material in the Tools section; and estimate specific challenges of an area; for example, zone of mudflow hazard can influence significantly.

The landscape analysis conducted for Almaty Agglomeration established the following landscape zones in the area of consideration (Figure A1.2):

Figure A1.2. Diagram of landscape zones of the territory



- **Deserts and meadows.** Landscape zone north of Almaty, which creates strong limitations to tree planting. This zone grows drought-tolerant plants on watersheds and native woody vegetation on floodplains.
- **Steppes.** Steppe landscapes are mostly urban now. There are fertile chernozem soils that enable diverse vegetation growth through urban watercourses and artificial irrigation, although the heat island effect and development pose challenges to greenery in this zone.
- **Mountain meadows and forests** facilitate healthy growth of woody vegetation and fresh mountain air flow to urban areas. They play vital roles in retaining rainwater and snowfall, preventing mudflows, and recharging groundwater. Therefore, reforestation in river watersheds is a priority.
- **River valleys** offer great landscaping potential with riparian forests, reliable water sources, and fertile soils, although they face risks of mudflows and seasonal floods. The northern valleys of Almaty are notable, as the southern part lacks significant valley formations on the landscape map.
- **Barchans sands** are a challenge for landscaping as water remains far from the surface and does not retain in the sandy soil.
- **Saline deserts and meadows** receive more water than sandy deserts, but the presence of salt in the groundwater restricts the range of plants that can survive in these soils.
- **Agricultural land** is the type of land use in different landscape zones. It can provide fertile areas with potential for landscape restoration and innovative silvopasture practices.

Source: MLA+ .

Almaty Agglomeration has several landscape zones that change from north to south. There are four basic types of natural landscapes: deserts, steppes, mountains, and river valleys. There are specific processes for ecological restoration of natural vegetation and planting of new plants in different types of landscapes. Barchan sands and saline areas should be considered separately—they create strong limiting conditions for landscaping.

The landscape assessment of the territory also made it possible to draw an important conclusion for the green network design; its main axes should run along rivers. River valleys have the greatest value and biodiversity. In addition, this landscape type runs through all other landscape zones, connecting them to each other.

The data for landscape assessment are geological maps (especially quaternary), topographic maps, and data on vegetation, soils, water regime, as well as historical data. The analysis was performed using geographic information system (GIS).

A1.3. Asset Assessment

Asset assessment is used to inventory all resources available, which can be used to create a green network. The assessment identifies existing conditions of assets and potential for improvement and determines what elements are missing from a cohesive network.

There are four main asset analyses: water, green, recreational, and area future transformation (Figure A1.3–Figure A1.6).

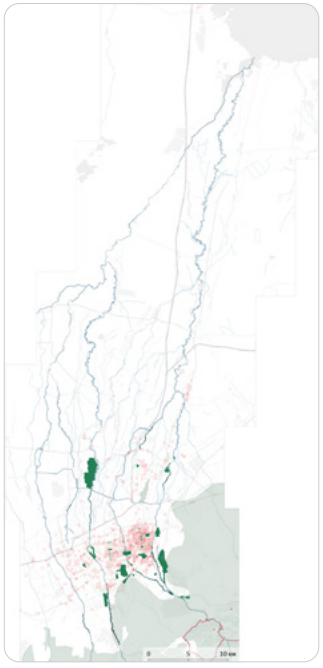
Figure A1.3.
Water assets

Source: MLA+.

Figure A1.4.
Green assets

Source: MLA+.

Figure A1.5.
Recreational assets



Source: MLA+.

Figure A1.6.
Future Transformation

Source: MLA+.

Water assets (Figure A1.3) are essential for Almaty Agglomeration, with main rivers like Malaya Almatinka, Esentai, Bolshaya Almatinka, Boraldai, Kargalinka, and Bolshoy Almatinskiy Canal acting as vital corridors, connecting ecological cores, supporting biodiversity, and sustaining natural spaces. Additionally, these watercourses create important air corridors within urbanized areas and hold historical significance for Almaty. However, the territory faces challenges associated with its water

assets, including mudflow hazards, the canalization and alteration of rivers for mudflow protection, chaotic development in water protection zones, and the need for water resources for irrigation due to the arid climate.

Green assets (Figure A1.4) refer to the valuable ecological cores and green riverbanks of the main rivers, forming the foundation of the green network using Landscape ecology theory (Dramstad, Olson, and Forman 1996). These cores (or patches) are large green areas with high biodiversity and environmental stability. Corridors are essential for the exchange of flora and fauna between cores, while the matrix represents the background territory (for example, urban territories, agricultural fields). The main threats to the green asset in Almaty Agglomeration are fragmentation of green cover, destruction of riverbanks due to development, and lack of connectivity.

Recreational assets (Figure A1.5) refer to the unique spaces that provide opportunities for leisure, relaxation, and sports activities for residents. These assets include green areas, parks, landscaped riverbanks, routes, and existing amenities, with the potential for outdoor activities, such as walking, jogging, cycling and other, being enhanced by green riverbanks and nature-inspired design solutions.

Future transformation assets (Figure A1.6) comprise planned projects within the territory, including urban park improvements, outdoor training paths, and urban development. Notably, the G4 strategy proposes significant urbanization along the Almaty-Konaev highway, resulting in a 3.5-fold increase in urbanized areas, affecting the natural boundaries of the river valley and reducing its size. Evaluating the protection status of future green corridor sections within the planned land use becomes crucial, and recommendations for adjusting the location of urbanized cores in the G4 project within a green network should be considered to preserve valuable landscape assets.

The assets mapping for Almaty Agglomeration was conducted based on data provided by Almaty authorities and open resources in GIS programs.

Annex 2. Best World Practices for Creating Recreational Routes

Figure A2.1. Route map

Source: https://mavink.com/explore/Missouri-River-Route.

Route along the Maas River

Length: 480 km

Travel time by bicycle: 8 days

Type of bicycle route: asphalt, unpaved

Infrastructure on the route: camping/ navigation/picnic tables

The LF (Landelijke Fietsroutes) Maasroute route is along the Maas River in the south of the Netherlands, beginning in Maastricht and ending in Hook van Holland. Cyclists can enjoy beautiful views of nature; see fortified towns, orchards, and Dutch landscapes; and take advantage of ferries and hotels along the way (Figure A2.1 – Figure A2.3).

Figure A2.2. A bicycle route along the river Maas

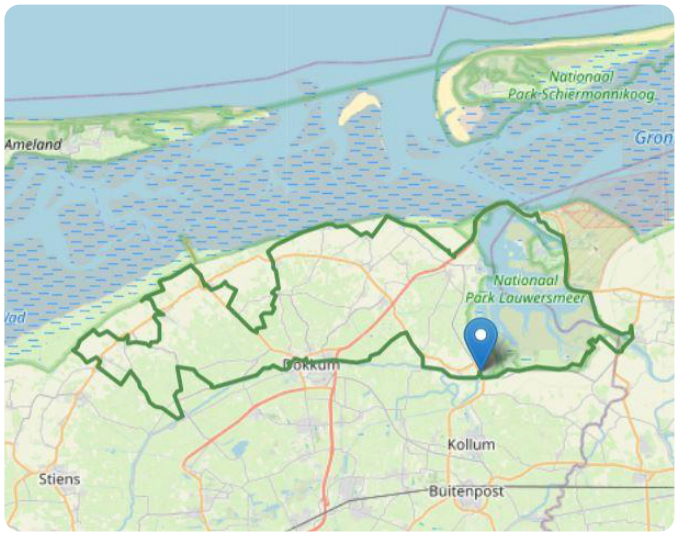
Source: Google Street View.

Figure A2.3. Camping stop for an overnight stay along the way

Source: Google Street View.

Techniques that can be used on a green corridor recreational route include creation of campsites, hotels along the route for overnight stays, and inclusion of orchards and agricultural land and farmsteads at the points of visit on the route.

Figure A2.4. Route map



One day itinerary in the province of Friesland

Length: 116 km

Travel time by bicycle: 3 hours

Type of bicycle route: asphalt, unpaved

Infrastructure on the route: navigation/ information boards

The bicycle route passes through Lauwersmere National Park and allows you to visit Dokkum, ride the levees and historic villages, and explore the history of the Wadden Delta (Figure A2.4–Figure A2.6).

Source: https://www.nationalgeographic.com/travel/slideshow/paid-content-take-the-road-trip-of-a-lifetime-along-the-wales-way.

Figure A2.5. Bicycle lane separated from the roadway by a strip of greenery

Source: Google Street View.

Figure A2.6. Viewpoints along the route

Source: Google Street View.

Techniques that can be used on a green corridor recreational route include creation of viewing platforms on the route; equipment of recreation areas by the water; in places adjacent to settlements, division of the surface on the bicycle path and the roadway to ensure safety.

Figure A2.7. Route map

Devon Coast to Coast

Length: 157 km

Travel time by bicycle: 8 hours and 20 minutes

Type of bicycle lane: 58.7% isolated bicycle lane, 41.3% along the roadway

Infrastructure on the route:

- benches - every 1.5 km on the non-traffic portion of the route
- picnic tables
- lean-to shelters
- navigation
- information boards

Type of surface on the route: unpaved road/ asphalt

The Devon Coast to Coast route combines the beaches and estuaries of North Devon with the lush green valleys of Torridge, Tawy, Walkham, and other West Country rivers (Figure A2.7–Figure A2.9).

Source: https://www.sustrans.org.uk/find-a-route-on-the-national-cycle-network/devon-coast-to-coast.

Figure A2.8. Part of the route runs along the seashore

Source: Google Street View.

Figure A2.9. A bicycle parking lot is placed at the point where the route connects to the settlements

Source: Google Street View.

Techniques that can be used on a green corridor recreational route include equipping the entrances to the recreational trail with an installed stand with navigation and bicycle parking.

GREEN CORRIDOR PLANNER GUIDELINES
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