MATERIALISING RESILIENCE

OPEN DATA MANAGEMENT, FLOOD RISK ASSESSMENT AND OPERATIVE ACTIONS FOR DYNAMIC CITIES

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“All of humanity now has the option to ‘make it’ successfully and sustainably, by virtue of our having minds, discovering principles and being able to employ these principles to do more with less.”

Richard Buckminster Fuller

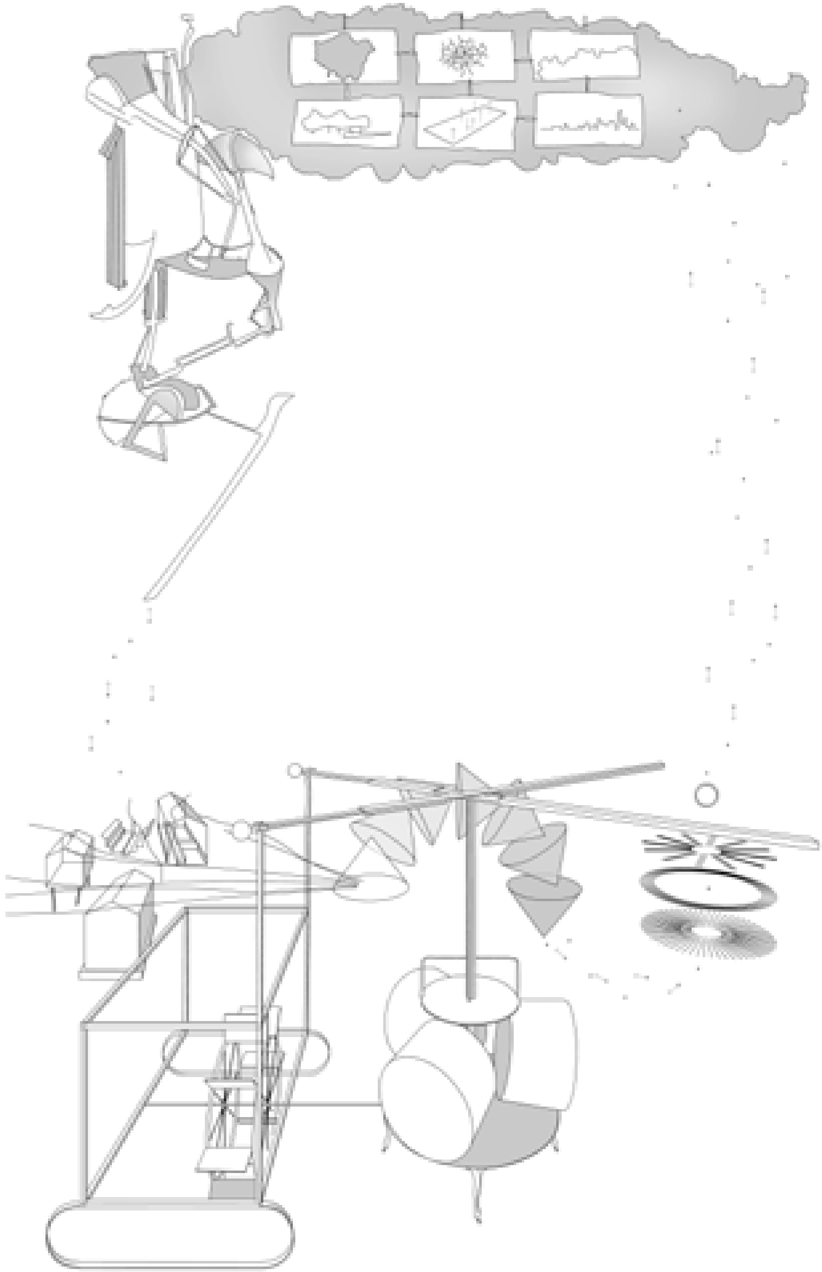
ABSTRACT

The aim of this research is to explore new possibilities in architecture and urban design allowed by advancements in digital mapping. Our awareness of changes to the environment and increasing ability to utilise real-time data allow us to respond to these changes through the design process. Given the importance of new technologies in aiding the planning process, it is surprising that Governmental Agencies have been doing very little work trying to connect virtual and physical realities. The architecture of the city depends only on considering the territory as a whole, and maps are the platform on which it is possible to study future actions.

As big data analytics become more advanced the information becomes easier to extract and utilise. Therefore, traditional maps cannot satisfy current needs any longer. If the correlations between data have changed, and consequentially maps too, politics of spatial management must be modified as a direct consequence. The ability to make instantaneous changes to maps reduces the gap between physical and digital domains. Through the interweaving of these two realms, one could change the awareness of cities' dynamics. Moreover, the direction that strategic planning should take can be better understood.

The goal is to provide architects a multi-scalar platform allowing them to use one single dashboard to access multiple layers of information. The *Telematic Map of Risk* unveils new relationships and connections between buildings and their context. As GIS-based map, it shall be considered as a multi-hazard tool aimed to form and support decision-making processes of Local Planning Authorities, to foster disaster resilient societies. Using the digital map, architects no longer design within a fixed environment, but create infrastructures that allow the urban fabric to change over time. By creating a hybrid system of design that positions itself between top down urban planning and bottom up city growth, the maps will allow architects to create an organised framework—based on the *Cluster Plans* and the *Guidelines for Territory Planning*—within which buildings can be designed.

Methodology of the *telematic map of the risk*, faithfully adapted from *Le Grand Verre* by Marcel Duchamp.



0 PROLOGUE

Scientific field

Technology: *τέχνη*, art, plus *λόγια*, oracles. Doctrine of the direct application of physical, chemical and mathematical disciplines to the arts and crafts, so that anyone do not operate against the mere scientific principles (Cortelazzo, 2004). The very definition of «technology» has driven the whole studies of this research over digital mapping and water management in strategic urban vision that has global warming as core of its reasonings. New technologies and computational systems shall be used to provide architects operative tools for designing the flexibility of the city to come.

Within *Architectural Technology*, this research intends to give its contribution to the sector of 'innovative technologies for urban and architectural redevelopment'.[1] These studies take sources from many fields, and in this sense it is possible to set them into an hybrid domain. This dissertation for the Degree of Doctor of Philosophy in Architectural Technology is aimed to reconnect urban development to the dynamism of catastrophic events caused by natural phenomena. The continuously changing features of hazards and, thus, risk can be better understood analysing real time data coming from public Agencies and private users of electronic devices. Operations with immaterial technology systems are facilitating the awareness of the totality of environmental phenomena. In particular, in this research the analyses of risk are focused on water dynamics and floods, in order to present a series of practical criteria to design new settlements on brownfield areas marked by a high level of vulnerability.

Architecture 'has a reputation for being innovative but also slow to change established habits'.[2] As socio-economic dynamics are nowadays way faster than a decade ago, and cities have been undergoing an incre-

1 MIUR, *DM 4 ottobre 2000, Annex A*.

2 Emmit S., 2002, *Architectural Technology*, Blackwell Science Ltd, Oxford.

asing level of complexity, the role of architects cannot be the traditional designers of buildings, blocks, etc. anymore. Cities are dynamic entities characterised by socio-cultural affairs and settlement issues. Moreover, many phenomena related to global warming are going to be crucial in the challenge of our alive cities.

Only interweaving the information and communication technologies (ICT) to traditional designing methods, the rapidity of immaterial changes could be projected onto cities, at the city scale.

As said, *Immaterial* and *Architectural Technology* shall be considered as an *unicum*. There cannot be any future development at city scale that is not going to be driven by something larger, and there cannot be any territorial change that is not going to be strictly connected to local mutations. While small-scale design can be often managed simply throughout the use of traditional systems, large interventions within cities need a dashboard capable to simplify the overabundance of information. That is, in order to entirely control the city, gathering all the datasets coming from Agencies and private stakeholders is necessary. In architecture, choices cannot be taken avoiding the context. So, as cities are growing fast, and digital information too, architecture is going to be considering the huge amount of data available to be more prone and flexible to future needs and changes. Once the globality of urban systems is understood, guidelines for future development at the architectural scale are the litmus test of an operative network.

During this dissertation *Risk Assessment and Management* assume a crucial importance. Risk assessment is the process of estimate the consequences of hazards and their likelihood. It involves three steps: the hazards identification, the studies of potential consequences, and the assessment of the probability of the consequences. Assessing the quality, reliability and relevance of experimental or empirical evidence, and the underpinning conceptual model, is an important part of risk assessment and management[3]. As strategic planning is based on real phenomena, the identification of natural and man-made hazards can help in the prioritisation of the use of resources. The evaluation of all the sources of risk supports the creation of a global vision of the hazards, and the awareness of how to deal with them. One of the aims of this thesis is to demonstrate that many impacts from hazards can be reduced by investing in adaptation strategies in the medium and long term.

3 Gormley Á. et al., 2011, *Guidelines for Environmental Risk Assessment and Management*, Crown Copyright

Another field of this research is *Spatial Analysis and Modelling*. The studies of spatial entities, through their topological, geometric, and geographic properties, allows the comprehension of the relationship between objects in the space. Then, the fourth dimension of 'time' can be easily integrated with spatial analysis thanks to the use of real-time data. Predictive modelling takes great benefits from computational analysis of geographic relationships. Spatial analysis is at the very heart of geographic information system (GIS) technologies. Through the effective use of GIS-based analyses and mapping, it is possible to shape people's behaviour and settlements' connectivity across a region.

Digital technology, geospatial analysis and physiography play a complementary role in the development of this dissertation. The know-how of such diverse disciplines forms the spine of innovative urban planning and architectural design. Digital technology grounds the methodology; geospatial analysis provides the tools; physiography supplies knowledge. By gathering capital knowledge about risk and immaterial technologies, the aim is to connect them to urban planning and architectural design, and to show possible future scenarios these links can create. As a result, data manipulation becomes urban and architectural design together.

State of the art

The visionary projects of changeable structures proposed by metabolist and structuralist architects, and *avant-garde* architectural groups in the Sixties invoked debates on technology and society. The economic boom nudged architects as Peter Cook, Aldo van Eyck and Fumihiko Maki to keep up with contemporary society, designing the architecture of flexibility and propagation. All their thoughts were focused on erratic and growing cities, boroughs, and buildings. It was the architecture of the totality: any spatial entity was designed to be able to react to contingency and social needs, as alive organs of a larger organism.

Archigram's *Plug-in City* and *Walking City* are constantly evolving machines at the scale of the city, which go far beyond the common idea of collective living and transportation system. 'The aesthetic of incompleteness, [...] derived from the construction sites of the building boom that followed the economic reconstruction of Europe[4]', was clearly a rejection to modernist precepts. The dynamism of the city was the centre of urban process, again, in an innovative way.

The raise of radical architecture, due to the missed delivered of social happiness promised by modernists, highlighted the ethical implications of architectural choices. Architecture necessitates to overlap to the social and political rules of the community. Ethico-political—meaning 'of the pólis'—ideals cannot be abandoned by architects, because there is no architectural choice that does not have socio-political implications. Sometimes contemporary architecture missed the task of forming ethical and political relations between technology and aesthetics. 'For, just as some modern architects had engaged mechanical technology with such ideal in mind, contemporary architects [should] continue to harness and to radicalize the transformative prospects opened up by new technologies.[5]'

As technology evolves, tools and communication languages change as well, but the aim of fully control the city lingers. Nowadays some telematic dashboards, as *citydashboard.org*, are able to show on one page a number of information about weather, traffic, tube line status, etc. Then, other platforms collect many datasets, mainly from governmental Agencies, gathering information about jobs and economies, transportation, the environment, housing, health, tourism, etc. Both the typologies of websites are real-time or nearly real-time sources of data and information. Through these tools one can download and correlate data, obtain and compare information. The city is very open to anybody, but what is currently underestimated is the use of these datasets to crate interrelations with predictions of natural phenomena. Particularly, big data regarding water features (flow, level, etc.) in specific places is not put in relation to people's locations yet, while this correlation could describe risk more accurately and dynamically.

Water dynamics studies have always been a beacon for communities grown up on rivers and coasts. Engineering works began with the first agricultural settlements more than ten thousands years ago. Nowadays the surprising advancements concern both technological precision, and the dimensions of sites. But all in all, what is not widespread developed is the connection of infrastructures to the various parts of the city (e.g. roads to buildings, canals to parks, etc.). Apart from the Netherlands, most of

4 Sadler S., 2005, *Archigram. Architecture without architecture*, the Massachusetts Institute of Technology Press

5 Scott F.D., 2007, *Architecture or Techno-utopia. Politics after Modernism*, MIT Press, Cambridge MA, p. 86.

water management and strategic planning regards only infrastructures. Hence, the thesis proposes to focus on the creation of systemic interventions, where infrastructures allow flexible interventions capable to maintain their functionality in high and low tide conditions.

Even though many models have always driven urban redevelopments and infrastructures, they were mainly based on economic evaluation of trends, static maps of risk, predictions of migrations, or so on. Great examples of the importance of forecast models such as the *Lu Jia Zui District* in Shanghai (1992) by Richard Rogers[6] and the *Xiamen City Energy Masterplan* (2009) by Chora[7] offer wide overviews on potential models to take advantage of. All these scientific models, albeit accurate, does not usually give real-time representations of reality, and thus the forecasts are in a sort of delay. That is, the gap between any survey and the very instant that has just passed by generates a lack in flexibility, as the instantaneous variations need a more adjustable infrastructure—physical or telematic—to be set on. As their occurrence is based on short periods of time compared to human's existence, catastrophic events need to be studied instant by instant, as well as the ordinary conditions of their sources.

Aims and limitations

The book *Architettura come dis-identità. Teoria delle catastrofi e architettura (Architecture of the dis-identity. Theory of catastrophes and architecture)*, by Carmine Benincasa, inspired the idea of dealing with catastrophic events. Arguing there is always a breaking-rules event that changes the continuity of things, the author focuses on qualitative variations of any discipline (both the scientific and the artistic ones.) The Hegelian considerations over the dichotomy of qualitative and quantitative changes are oriented to the definition of events through the extrinsic features of qualitative mutations. Qualitative changes do not determine quantitative variations, while a mutation in quantity could cause qualitative changes. This statement is clearly true about the use of big data and open data.

As it happens in big data gathering, one knows where to look for something, and what to look for at the beginning; but one is not sure at all about the unforeseeable correlations there will be creating, and neither

[6] Rogers R., Gumuchdjian P., 1997, *Cities for a small planet*, Faber & Faber, London.

[7] http://www.chora.org/?p=56

about the outcomes. The research started with no targets, and no limitations *a priori*, but with the aim of rethinking the way human kind is trying to control the nature and building resilient cities.

Since the 20th century, architects have always been trying to redesign not simply parts of the city, but the entire society, and the city as a whole. The social control Charles-Édouard Jeanneret-Gris lavished his projects is the proof of a new era, an *«esprit nouveau»*. This top-down vision comes from the will of creating something all-embracing and perfectly working, after the tragedy of the wars. The architect acts as a clockmaker, careful of making all the gears working. Indeed, from the *Ville Contemporaine* onwards, a new paradigmatic idea for people's lives was created. Technological progress would have changed both the way of building and inhabit buildings. It would have changed people's life standards and city efficiency in better.

Even though the utopia of rebuilding the city of future from the ground became quite often a dystopia, more than a desirable place where to live, the soul of the powerful manifesto is still alive. In fact, as technology is running fast—definitely faster than architecture—architects are aimed to integrate new technologies to urban planning and buildings design. Unfortunately, the isolation of architects, who are often looking for their own glory (and that is it), is pulling them away to social issues. The rising number of the so-called 'archistars' can only shift the cultural features of architecture to the mere visibility of their pieces.

Aim of this research is to gain a telematic infrastructure to control the high amount of information coming from many datasets, which can simplify over-complexities. It shall help designers to keep their focus on the city, instead of being building-centric. The intent of the *Telematic Map of Risk* is to connect urban developments to risk analysis, in order to guarantee flexible planning. This means that urban fabrics—that depend on the infrastructures—will be able to be modified depending on the level of hazards predicted. Thus, these changes shall be set in relation to two manifestations of time: the evolution of the local level of risk, and the local velocity of the building stock transformation.

Architects have always been able to speak present languages, and use present communication devices. They cannot stay away or behind essential elements of the society. Digital immaterial technologies are nowadays the easier language to gather vast information to improve urban and architectural design. There is no other way: that would be the past. The mutuality between culture and the urban environment is innate in the very nature of the city.

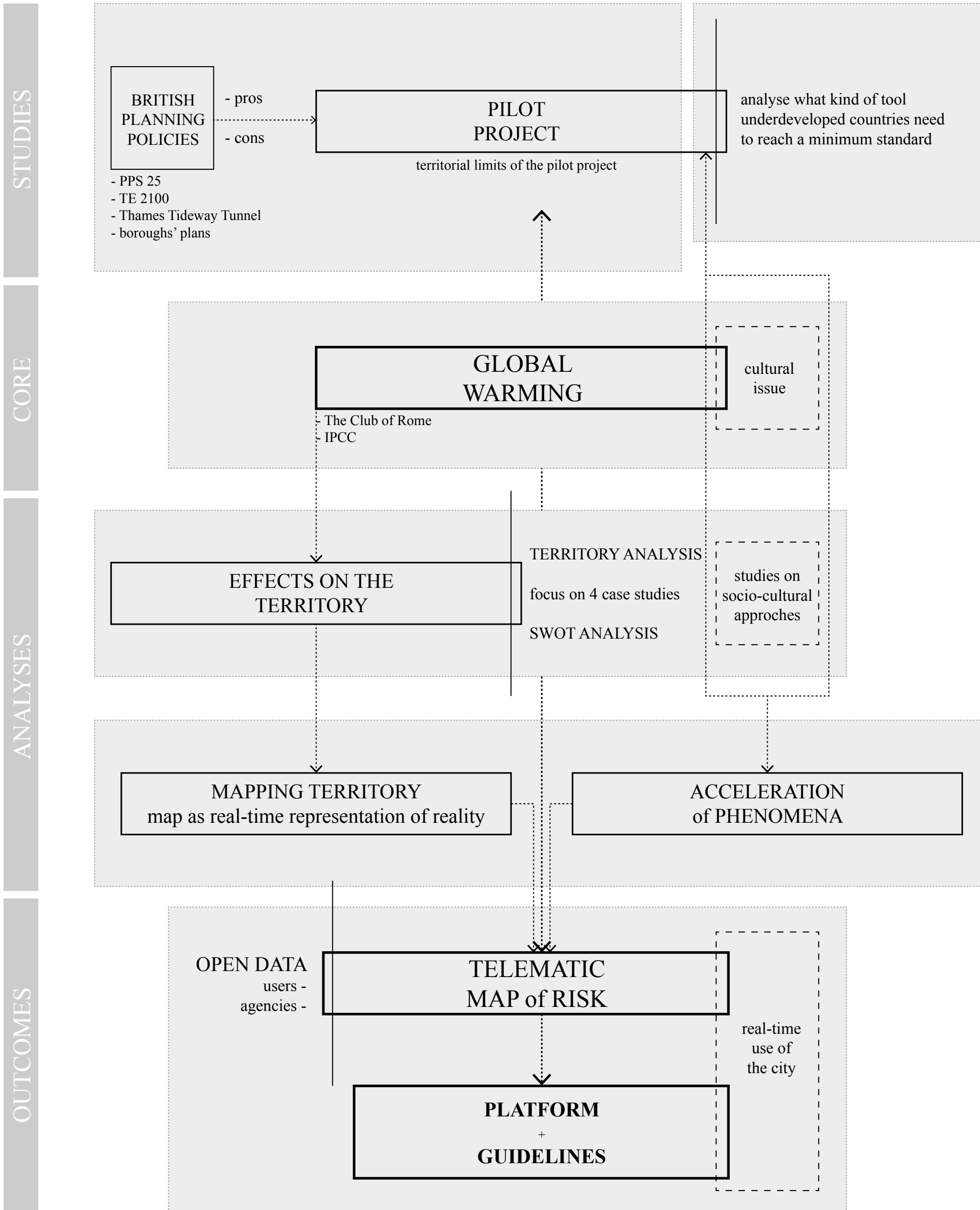


Fig. 0.1
Research scheme.

Traditional mapping systems, based on static views of spatial entities, cannot satisfy current needs any longer, as satellites provide more data, quicker. If the correlations between data have changed, and consequentially maps too, politics of spatial management must be modified as a direct consequence. And data shall be given a scale. The ability to make instantaneous changes to maps reduces the gap between physical and digital domains. Through the interweaving of these two realms, one could change the awareness of cities' dynamics. Moreover, the direction that strategic planning should take can be better understood.

The choice of focusing the research on cities of technologically developed countries is due to the contribution they can give both to places where ICT systems are part of the city strategies, and to those where ICT devices are not even considered. Indeed, a small improvement in digital systems can start a vast revolution in the way strategic planning is elaborated. For instance, the use of telematic monitoring devices, or the adoption of open dataset about landform variations, can introduce the process of planning considering risk as an extrinsic quality of space. In the light of these considerations, what could be commonly considered a limitation becomes a call for reaching minimum technological standards.

All in all, the dissertation will be focusing on two main complementary aspects, i.e. the creation of a four-dimensional *Telematic Map of Risk*, and its use by designers. Then, an explanation of the capital data needed for the map will be conducted. Finally, the information deriving from dataset will be compared, representing three different levels of public availability and awareness.

Methodology and implementation steps

We must be aware it is not true that methodological process is an untouchable, inviolable and dateless entity. One could think that even though technologies, tools, approaches, etc. are constantly changing, methods and principles are steady *itinera*. During this dissertation the opposite will be shown: methodology influences technology right as technology influences methodology. '[R]eflection on method usually follows practical application, rather than preceding it.'[8] If operative principles change, thus the methodology might be changing as a direct consequence. For instance, a re-

[8] Agamben G., 2009, *The Signature of All Things. On Method*, Urzone Inc., Brooklyn, NY.

volution in data gathering can totally flip the consolidated method of data analysis, as a innovation in building design can revert the urban planning criteria. The relationship between quality and quantity regarding datasets, and then information, can unveil a different step that was not considered before, or that was considered wrong. It is not an aggrandizement of relativism, but simply a consideration on the possibility of change of some criteria of research.

The dissertation is built on three parts. Chapter One describe all the basic principles of catastrophic events, risk assessment and management, and vulnerabilities due to global warming. In Chapter Two the discussion focuses on deep analyses on the relationships between human kind and water, then on how innovative immaterial technologies can change the perception of realities, and how they can help us in mapping dynamic phenomena related to water. Chapter Three aims to eviscerate the way architectural design and urban planning can take benefit from smart combinations of traditional and innovative technologies. This part of the research analyses how to simplify over-complexities of our cities through the use of real-time systems, and how to provide architects flexible operative guidelines to increase cities' resiliency. Finally, a fourth summarising chapter is dedicated to the limitations of the methodology adopted, and its future pragmatic applications in risk management.

This thesis is articulated in three components tightly connected over the entire dissertation. These are, methodology, philosophy, and design. The choice of not reserving each one of these a specific chapter is due to the need of develop a coherent discourse capable to connect the three aspects of the research. Moreover, to correlate them continuously allows for an easier comprehension of the variety of topics analysed.

The core of this this dissertation is the way global warming can affect our life in the city. Climate change is a global cultural issue that is partially disjoint to the very territory where strategic planning is designed. Population have always been quite conscious of how nature changes humans' habits and behaviours. To prove it, and obtain accurate feedbacks, a series of SWOT analyses has been conducted, so that socio-cultural approaches to natural phenomena could be investigated. Once the effects on territory are clarified, precise studies on a specific site can be conducted. In so doing, the general principles emerged from the SWOT analyses becomes pragmatic on one area of interest. The comprehension of project dynamics is centred on planning policies and local studies of existing entities. The methodology adopted works from the particular to the universal, and then back to the particular again. In fact, the research has begun studying a specific site (the pilot case) and other study cases, in order to understand the very nature of the relationship between man and water.

From these concrete analyses, and the real-time mapping to represent both reality and future scenarios, the possibility to create a general dashboard was gained. The *Telematic Map of Risk* is an innovative digital platform based on open data gathered from common users and Agencies, which gives architects specific design tools. These are built on guidelines divided by their relationship with water. Finally, the platform necessitates to be verified, being tested on the specific case again, for being the proof of a flexible instrument that allows different results for different approaches to one hazard.

Then, it is possible to compare a number of cases with different levels of data gathering, and fix the minimum prerequisites to operate in the direction of *Telematic Map of Risk*. In so doing, we can state that this method can be broadly applied, and analyse what kind of tool underdeveloped countries need to reach a minimum standard.

The outcomes of this dissertation open many scenarios for further plug-ins and researches. Firstly, the analyses conducted on water-related catastrophic events can be implemented with other natural and man-made hazards. Indeed, the more complete the studies over risks, the more accurate map we shall create and investigate on. Secondly, being a flexible platform, the dashboard must be changed and expanded in every component. As technologies evolve, the possibility to develop more accurate tools of analysis is self-evident. Moreover, the outcomes of this research can be useful for other sectors aimed to connect virtual to physical reality. Both architectural and risk management sectors are seeking to find technological and information transfer from and to other disciplines.

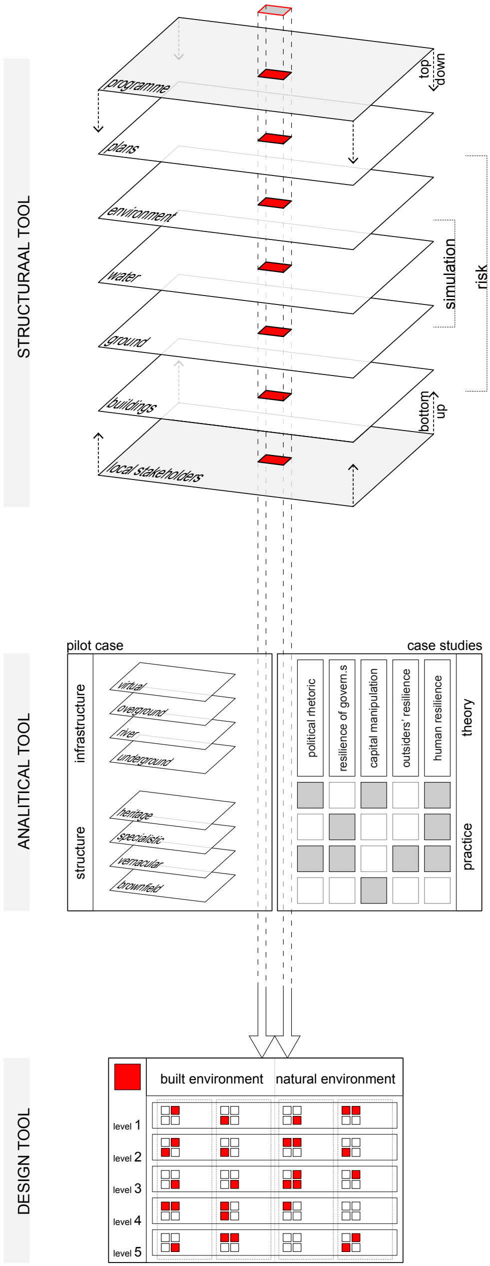


Fig. 0.2
Methodological process.

Questo capitolo introduce le componenti teoriche della ricerca. Inizia trattando la distinzione fra catastrofi e disastri, nella Sezione 1.1.1, e la scala di questi fenomeni nella Sezione 1.1.2. La Sezione 1.2.1 presenta la teoria delle probabilità applicata a eventi disastrosi di scala vasta, mentre i conseguenti comportamenti delle persone sono analizzati nella Sezione 1.2.2. Il surriscaldamento globale ed le relative questioni temporali sono introdotte come cuore di questi studi nella Sezione 1.3.1. Infine le tematiche relative alla vulnerabilità della società sono studiate nella Sezione 1.3.2 e sono finalizzate a fornire principi per la progettazione strategica.

This chapter is an introduction to the theoretical background of the research. It starts with the distinction between catastrophes and disasters in Section 1.1.1, and the scale of these phenomena in Section 1.1.2. Section 1.2.1 presents the probability theory applied to disastrous large-scale events, while human behaviours are analysed in Section 1.2.2. Global warming and its temporal issues are introduced as the core of these studies in Section 1.3.1. Finally, the topics related to societies' vulnerability are investigated in Section 1.3.2, in order to provide principles for strategic planning process.

1 NEW PERSPECTIVE ON FICKLE PHENOMENA

Catastrophes, morphogenesis, and disasters

When a catastrophe becomes a disaster 1.1.1

κατάστροφή *from Greek κατά [katà, «down»] plus στροφή [strophē, «to turn»], 1. to upheaval, to overturning, to turn upside down - 2. end, result.*

There are some words that fascinate us. That is, they make a strong impression on us both because they are words with a profound history behind them, and because they have deep metaphorical meanings. One of these is the word «**catastrophe**», which etymologically means «upheaval» and indicates—as explained by Polybius and Lucian—the resolution of a tragedy, the cathartic moment.[1] "They [Hannibal's army] are, in fact, in the same case as tragedians who, beginning with an improbable and impossible plot, are obliged to bring in a *deus ex machina* to solve the difficulty and end the play." (*Histories*, 3:48.8,9) The upheaval is indeed to drastically change, metaphorically 'to fall down', thus an indication of time and spatial data. It takes only negative connotations, since the catastrophe is literally a turn towards what is below, towards the end, the bottom and the abyss. When the ancient hymns were addressed, it is clear that they referred to the chthonic deities of the underworld.

The earliest mythological forms of catastrophe coincide with the downfall even in the biblical cosmogony, when the lustful rebel angel made itself an enemy of God and men. It is not only a force, but a being endowed with intelligence, freedom and responsibility. So even in its existence there is a moral choice: the angel was put to the test to see whether he recognised God as the divine entity. In failing to do so, this angel became Satan, the 'inverted' angel who reigns over hell: "He was hurled to

[1] Rocci L., 1943, *Vocabolario Greco-Italiano*, Società Editrice Dante Alighieri, Roma; p.1007: Polybius, Greek historian of the Hellenistic Period, 'Ιστορίαι (*Histories*, 3.48.8), II sec; Lucian of Samosata, Greek rhetorician and satirist, Αλέξανδρος (*Alexander*, 60), II sec.

the earth, and his angels with him [...] and cast [in]to the bottomless pit".[2] Equally, the expulsion from Eden is an example of a catastrophe as well.

In considering catastrophes from the scientific point of view, in the 18th century Georges Cuvier supported 'the hypothesis of revolutions and catastrophes'.[3] According to this theory, the Earth would have been the scene of subsequent catastrophes that have periodically caused the extinction of many species of animals, due to radical changes of geological and environmental conditions. Cuvier's hypothesis, formulated to oppose evolutionism, was definitely a scientific catastrophe itself as soon as *The Origin of Species*[4] has been published by Darwin. It remained a valid thesis just for few of the great episodes of change in the Earth's biota, such as the extinction of Cretaceous-Tertiary Period.

The term appeared for the second time in the scientific field with the development of *Catastrophe Theory* by the French mathematician René Thom (1968-1972), which dealt with discontinuous catastrophic events in the study of dynamic systems (**differential calculus**). It refers especially to the study of natural phenomena, and in particular biological morphogenesis, resulting in the breaking of a morphological and structural balance.[5] The concept was later generalised to the process of morphogenesis, which became applicable to the study of all those systems whose actions change discontinuously in the continuous variation of a certain set of parameters. Small variations in certain parameters of a nonlinear system can cause stability to change, leading to widespread and sudden changes. Thom's *Catastrophe Theory* establishes a link between the regions of cause and effect: the causes, whose actions vary continuously, can cause discontinuous effects. It is therefore necessary to describe the form of all possible behavioural surfaces for recording the moment at which the invariant is broken, the balance is upset, and the catastrophe occurs: the structure of the evolution of one system (its trajectory) is now changed in a process of discontinuity of the analysed event.[6]

differential calculus *deals with the study of the rates at which related quantities change. The primary studies in differential calculus are the derivative of a function.*

Analysing the cusp catastrophe (Fig. 1.1) it can be observed that it possesses the characteristics of bimodality and hysteresis. That is, there are two positions of equilibrium (C), but the state the system reaches depends

2 *The Bible*, Book of Revelation 12:7-9; 20:1-3; cf. *The Bible*, Isaiah 14:12-15.

3 Cuvier G., 1822, *Discours sur les révolutions de la surface du globe et sur les changements qu'elles ont produits dans le règne animal*, Berche et Tralin, Editeurs, París.

4 Darwin C., 1859, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, John Murray, Albemarle Street, London.

5 Thom R., 1972, *Stabilité structurelle et morphogénèse*, Interédition, París.

6 Arnol'd V. I., 1986, *Catastrophe Theory*, Springer-Verlag.

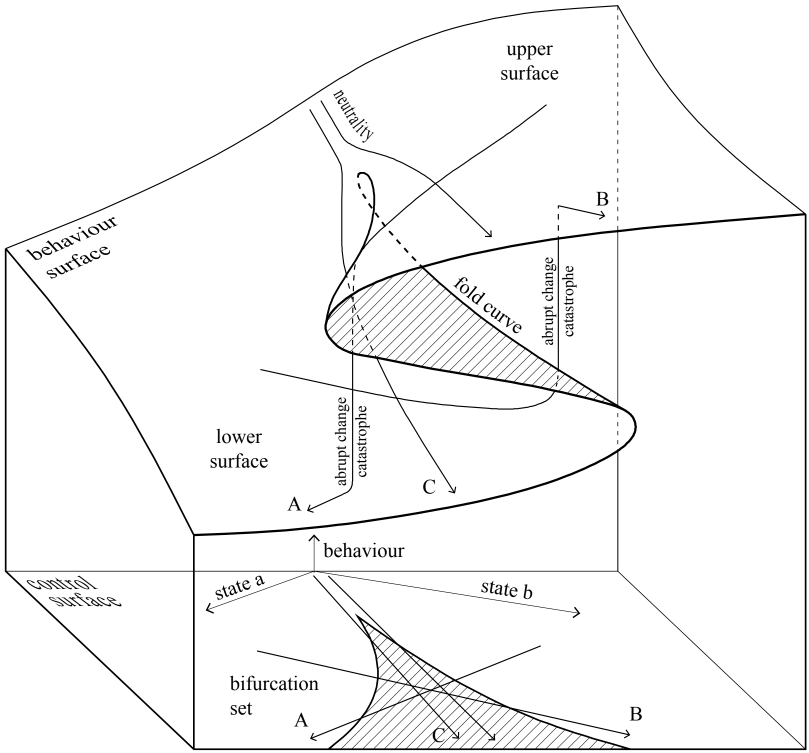


Fig. 1.1
A cusp catastrophe: $V = x^4 + ax^2 + bx$.

on the trajectory taken through the space. The third condition—the catastrophe—happens when the right- or left-hand fold is approached, and the outputs (A and B) are forced to jump onto the other part of the sheet. Once the catastrophe has happened, in that very moment a new form of balance is born. All the entities that characterise the phenomenon, all its spatial features, have thus acquired an advanced specific status. This new condition is not a static one, as everything is subjected to a more or less evident mutation.

The construction of catastrophic models applies to all discontinuous phenomena: market trend (upward/downward); phase transitions (liquid/gas); heartbeat (systole/diastole); linguistics (signified/signifier); theory of vision (figure/ground), related to the **Gestalt Theory**.[7] In all the meanings, «catastrophe» indicates a sudden movement downwards, a revolution into a new collapsed dimension, so—even though in shifted terms—the catastrophe reveals the existence of gravity forces. It reveals it in a literal sense: sinking ships, mountain landslides, earthquakes, etc., and in its figurative acceptation: the social, moral and economic downfall, such as prison riots, war outbreaks, or stock market crashes, e.g. Black Tuesday, 1929.

gestalttheorie
gestalt [shape, form] is a theory of mind of the Berlin School of Experimental Psychology. This field of modern psychology consists of two components: the psychology of formal qualities (Gestaltqualitäten) and psychology of form (Gestaltpsychologie).

The *Catastrophe Theory* was also interpreted by the Italian art critic and art historian professor Carmine Benincasa (1978). He argues that when architectural language is considered as a system, radical discontinuity in the centuries can occur as abrupt breaks of the code.[8] The catastrophe is a transitory phase from one status to another, due to precise features that determine it. What is important in the critical-iconological analysis is not the unitary structure of architectural projects, but the examples that create incompatibility with the language used so far. That is, what is incompatible with the widespread fabric: the architectural analysis is based on the topology of difference. In architecture as in music, variations of a hypothetical piece are the events that create tension and attention to listening (or viewing) and understanding.

> "If the history of thought could remain the locus of uninterrupted continuities, if it could endlessly forge connexions that no analysis could undo without abstraction, if it could weave, around everything that men say and do, obscure synthesis that anticipate for him, prepare him, and lead him endlessly towards his future, it would provide a privileged shelter for the sovereignty of con-

[7] Gestalt psychology or gestaltism.

[8] Benincasa C., 1978, *Architettura come dis-identità. Teoria delle catastrofi e architettura*, Universale di architettura, Dedalo libri, Bari.

> sciousness. [...] For, if it is asserted that the question of discontinuities, systems and transformations, series and thresholds, arises in all the historical disciplines (and in those concerned with ideas or the sciences no less than those concerned with economics and society), how could one oppose with any semblance of legitimacy «development» and «system», movement and circular regulations, or, as it is sometimes put crudely and unthinkingly, «history» and «structure»?"[9]

Discontinuities demonstrate how typological and language production is the standardisation of an 'entropic state' that tends to infinity. These exceptional events can be seen in the main stages of architectural history: the architect becomes the craftsman of history. He obligates buildings to be something different, for cities to be built on new principles, and for people to live in a different way. St Salvatore's church in Spoleto (Fig. 1.2) is the symbol of the collapse of linguistic coherence, a sort of forerunner ready-made; the Michelangelo's Laurentian Library is a great example of the crisis in the relationship between loads and support structures; the Mendelsohn's Einstein Tower represents the explosion and the relativity of matter. These are the most radical discontinuities, because they are inscribed within a work of theoretical transformation that 'establishes a science by detaching it from the ideology of its past and by revealing this past as ideological'.[10]

Reality consists of phenomena whose existence is manifested through their qualitative discontinuity: in most cases, the events undergo slow changes and their normal relative stability allows us to understand their multitude and diversity. The term «katà-strophē» reveals—metaphorically and in connection with its etymology—an important second meaning, the 'change of form'. The shape of a cloud, biological shaping within a growth or the slow and imperceptible descent of the foam in a glass of beer is slow-changing phenomena with catastrophic result. So, it is not possible to see the catastrophe as a threshold that marks a distinct change in shape without necessarily undergoing a large or too violent perturbation. There are no gradual catastrophes. This is particularly so in view of the fact that, as we have seen, the majority of phenomena are common among us and it is clear that they fall into the domain of «**metamorphosis**». These

μεταμορφώσεις *from Greek metamorphosis, metà- [after, over] plus morph-è [form, shape], mutation of physical form, structure, or substance.*

[9] Foucault M., 1972 (1969), *The Archeology of Knowledge*, Tavistock Publications Ltd, London, pp. 19, 20.

[10] Ibid., p. 4.

Fig. 1.2
Church of St Salvatore in Spoleto, 4th to 8th century BC, UNESCO's World Heritage site.

involve a profound change in the external shape and internal structure of events, appeared and asserted over its evolution, from an initial stage to a final one. Thus, forms have their own dynamics and, within their stable domain, situations in which small changes lead to big effects can be observed.

Metamorphosis can lead to catastrophes that provoke radical and violent changes at a certain point; and both of them can cause disasters. That is, metamorphosis and catastrophes can generate induced conditions, which occur when metamorphic or catastrophic events impinge on consolidated non-necessarily-stable states, tearing them down. At a singular point, a process ceases to be steady and one catastrophe—a discontinuity—appears, although causes are acting in a continuous mode; i.e., varying in a continuous manner, causes can provoke discontinuous effects.

disastrum *from barbarian Latin dis- [against, bad] plus astrum [star], which in turn comes from Greek prefix δυσ- [dus, bad] plus ἀστήρ [aster, star], calamity (historically blamed on an unfavorable position of a star).*

«Catastrophe» which means, as we have seen, to upheave, to overturn, to release from (action) has been associated—by amplification—**disaster**, misfortune, mourning. But this acceptation has to be considered wrong as far as we consider an avalanche in an uninhabited valley, or an earthquake in the Arctic[11]; those are catastrophes, not disasters. A «disaster» happens only when human beings or the man-made environment are affected: it is a critical situation due to a potentially destructive agent (catastrophic or metamorphic) that impacts a population caught in physical and or social vulnerability. It has long been understood as the 'class of death' that does not just involve an individual but also a group. As asserted by H.D.Beach (1967), disasters are "the relatively sudden and widespread disturbance of the social system and life of a community or of a large part of a community by some agent or event over which those involved have little or no control."[12]

Disasters fascinate human beings. We have always tried to seize someone else's misfortune in order to distance our lives from theirs. While, at the beginning, our primary need is to understand the phenomenon to fix it in our minds; the disaster itself then becomes a matter of study and prevention. Personal, familiar, or public alike, catastrophic events leading to disaster are always sudden. Everybody's perception of reality collapses, as humans discover that they are not the centre anymore. The fear that springs from this revelation is very subtle, but it lasts infinitely. What was imponderable becomes into discernible; the unforeseeable becomes pre-

11 Western K. A., 1972, *The epidemiology of natural and manmade disaster: The present state of the art*, The Academic DTPH, London School of Hygiene and Tropical Medicine, London.

12 Beach H.D., 1967, Management of human behavior in disaster, Department of National Health and Welfare, Canada.

dictable, and much real. What one fears most is what he does not know; then one tries to grasp it, in order to dominate and avert the anxiety. Observing a disaster on the other side of the world through media coverage, people try to absorb the devastation presented. It is an unconscious and morbid desire to live the experience intensely, and thus own it as an event that has not yet happened to their own community.

This dissertation aims to demonstrate that the understanding of the difference between catastrophe and disaster can lead to a more conscious management of social systems. The difference that exists is not a synonymous whim: it is about the relationship between time and environmental conditions.

The different quality of death 1.1.2

The collective destruction responds to a quantity policy, which leads to a different quality of death. The image of the collective death hovers around fiction movies but unlike what happens in those, ***Thánatos*** in reality takes on devilishly excessive, monstrous and paradoxical features. The death is no longer about the individual but the community, the country, the continent, the planet, and its determinants vary with the changing spatial and temporal contingencies. Furthermore, anthropological shocks irreversibly transform the way people think and behave. A disaster leads to the disruption of the natural world and to the tremendous distortion of the inner world of those involved.

Θάνατος *from Greek θνήσκω - [thnēskō, «to die»], was the daemon personification of death, son of Nyx (Night) and Erebos (Darkness).*

Disasters, although socially comprehensible, are extremely difficult to accept. But besides the causes, it is necessary to understand the social and cultural vulnerability conditions that led catastrophic or metamorphic events to be disasters. Moreover, the identification of the average risk perception within society concerning any event is extremely important, even though the population has reached a new stability condition. Indeed, disasters are apocalypse and genesis at the same time: once the catastrophic event occurred, it takes on a new form of stability. For this reason, in this discussion we shall give the term «catastrophe» a positive acceptation and the term «disaster» an active meaning of futurity.

The optimism in the future that characterised Europe until the 19th century let both aristocracy and common people think each event has a meaning, everything was eschatologically for the best. This divine plan was even promoted by philosopher as Leibniz, asserting that God had determined anything would happen in our lives. Then, Kant, Voltaire and Rousseau broke the rapport between religion and science. They claimed that disasters were not connected to any moral state of human beings, and they have been avoided, if society had organised itself in a different and more evolved way. Catastrophic events are part of nature, and we have to adapt to their dynamics.

> "The major interest in environmental disasters among today's research is a relatively new tern. Kenneth Hewitt has pointed out that even if our societies have always been hit by natural disasters, today's scientific understanding of them is young. [...] Many people were very interested in scientific and technological solutions to protect us from natural hazards. Knowledge of nature and development of nature was seen as being the most important factor, because natural disasters were considered inevitable consequences of the extreme process of nature. [...] The objective is a society without danger and there is a new wave of technological solutions on the way in.[13]"

Being aware that only the future will provide us the key of interpretation, to try and understand the very nature and social consequences of disaster is more important than ever. Disasters and catastrophes can be divided into two categories: anthropogenic and natural ones. The first are human-made events, and can be caused by negligence, unforeseen, mistake, or intent alike. Usually the deliberate human actions, such as terrorist attacks, structural collapses, transport disasters, etc., provoke catastrophes that propagate from the outer system to inside; vice versa, mistakes and negligence as CBRN contaminations cause catastrophes from the inner system to outside. Unforeseen hazards can provoke consequences in both directions. The hazards related to the anthropogenic category concern the natural environment, the built one and the society.

The second ones result from natural processes that could be both determined by a physical event only (earthquakes, lighting, solar storms, etc.), or the combination with an anthropogenic action (extreme temperatures, tornadoes, etc.). In this second case, the humankind is not directly concurring in increasing the magnitude of the catastrophe, but it is determining the alteration of the environmental condition that is provoking the natural event. The classification is specified in the table (Fig. 1.3a).

[13] Svensen H., 2009, *The End is Nigh. A History of Natural Disasters*, Reaktion Books Ltd, London.

The increasing complexity of global humanity's interactions (D.Chandler, 2015) is progressively dissolving the demarcation line between anthropogenic and natural phenomena. As humans are altering the environment at every level, the magnitude of anthropogenic events is rising, summing the impacts on the environment to natural hazards. The distinction between the two categories is strongly undermined, tending to not exist anymore. Thus, also the difference between direct and indirect human influence on natural calamities cannot be marked. Two are the main reasons of the collapse of traditional classifications. First of all, anthropogenic disasters can cause natural catastrophic events, and vice versa. These phenomena are often tightly interwoven, so that their pure identification is almost impossible. Secondly, the specific relation between human actions and natural event is frequently blurred. «Direct concausal» designates those events in which humans directly meddle with the sources of natural phenomena. He alters their natural states, halts their flows, and as a consequence, morphogenetic phenomena turns into catastrophes, and catastrophic events increase their magnitude. Instead, when we speak of «indirect concausal» events, we mean those whose sources are not affected straight by anthropogenic actions. In fact, these phenomena undergo changes caused by other natural or concausal events caused, in turn, by human actions.

As a result, a new classification can be developed (Fig. 1.3b): the differentiation between anthropogenic and natural events only regards the source and not the impact. As said, anthropogenic phenomena can cause natural disasters, and vice versa. Thus, all of them can potentially be concausal catastrophe and disasters, which means that the sensitivity of the environment rises significantly, reality becomes more complex, and data are more difficult to analyse. Scientific discoveries regarding the relationship between natural and anthropogenic events demands for urgent knowledge reorganisation, and immediate actions to be taken. We can enter a new kind of reality, where there is no distinction *a priori* between any sort of phenomena and catastrophic events. A reality, though, where the need of abstraction and environmental awareness is more necessary than ever before.

Particular attention must be given to those events in which human beings are actively altering the catastrophe magnitude. Within the 'direct concausal' category, flood is the one that caused the most devastating effects, involving the relationship between natural and built environment, and the man-driven alteration of them. In considering the main disasters by recovering costs, three out of the top fifteen is a flooding, and seven of

	nature	category	genre	
catastrophes and disasters	ANTHROPOGENIC	social disaster	crime and terrorism	
			war and disorders	
		technological disaster	CBRN contamination	chemical
				biological
				radiological
				nuclear
			explosion and fire	
			structural collapse	
		transport disaster	aviation	
			rail	
			road	
			sea	
			space	
		wildfire		
	NATURAL	biological infestation	biological invasions	
			epidemics	
		climatological catastrophes	drought	
			extreme temperature	frost weave
				heat wave
			wildfire	
		geophysical catastrophes	avalanche	
			earthquake	
			landslide	
			volcanic eruption	
		hydrogeological catastrophes	flood	
			limnic eruption	
			tsunami	
		meteorological catastrophes	blizzard	
			tropical cyclone (hurricane, typhoon, etc.)	
			lightning	
			precipitations	diamond dust
				hail
				ice pellets
				rain
				snow
			tornadoes	
			wind	
		space catastrophes	impact event	
			solar storm	
	CONCAUSAL	epidemics		
		flood		
		landslide		

Fig. 1.3a
Standard classification of catastrophes and disasters, by the Author.

these are water-related.

Chernobyl disaster, 1986, $455bn;
Tōhoku earthquake and tsunami, Japan 2011: $300bn;
Sichuan earthquake, China 2008, $148bn;
Deepwater Horizon oil spill, Gulf of Mexico 2010, $60-100bn;
Hurricane Katrina, U.S.A. 2005: $45bn;
Thailand floods, 2011, $45.7bn;
Hurricane Ike, United States, September 2008, $29.6bn;
Yangtze River floods, China 1998, $26bn;
Hurricane Andrew, U.S.A. 1992, $25bn;
September 11 terrorist attacks, U.S.A. 2001, $20.7bn;
Indian Ocean earthquake and tsunami, 2004, $15bn;
Christchurch earthquake, New Zealand 2011, $13bn;
Armero tragedy, Colombia 1985, $7bn;
Exxon Valdez oil spill, Alaska 1989, $6.9bn;
Alberta floods, Canada 2013, $3-5bn. [14]

Only few places on Earth are not subject to flooding: any place where rain falls is exposed, albeit rain is not the only cause for flood. A flood occurs when water submerges land that is commonly dry. This can happen in a number of ways. The most frequent one is when rivers or canals overflow their embankments, and water spreads over the adjacent land, called a floodplain. The causes of these phenomena may be due to fast ice melting in the glaciers or icebergs, excessive rain, particularly high tide, or a dam or levee collapse. Then, coastal flooding happens when a heavy storm or earthquake causes the sea to rise towards mainland for hundreds of miles.

Forecasts have reached quite high standards in developed countries, as most flooding events take many hours develop, giving people early warnings to be prepared to evacuate. Few times they strike quickly and with little notice (flash floods occur within six hours of a rain event), or no warning at all. These so-called ‘flash floods’ can be particularly perilous, inasmuch as they can transform tiny water paths into massive walls of water capable to sweep everything downstream. Floods are classified according to their possibility of occurring in a range of time. A hundred-year flood, for instance, means there is a one-per cent chance a year that such a large and destructive event could happen. Doubtless enhanced by global warming, in the last decades hundred-year floods have been happening

[14] Detailed references in ‘Notes’.

catastrophes and disasters

nature	*category*	*genre*	
ANTHROPOGENIC	social disaster	crime and terrorism	
		war and disorders	
	technological disaster	CBRN contamination	chemical
			biological
			radiological
			nuclear
		explosion and fire	
		structural collapse	
	transport disaster	aviation	
		rail	
		road	
		sea	
		space	
	wildfire		
NATURAL	biological infestation	biological invasions	
		epidemics	
	climatological catastrophes	drought	
		extreme temperature	frost weave
			heat wave
		wildfire	
	geophysical catastrophes	avalanche	
		earthquake	
		landslide	
		volcanic eruption	
	hydrogeological catastrophes	flood	
		limnic eruption	
		tsunami	
	meteorological catastrophes	blizzard	
		tropical cyclone (hurricane, typhoon, etc.)	
		lightning	
		precipitations	diamond dust
			hail
			ice pellets
			rain
			snow
		tornadoes	
		wind	
	space catastrophes	impact event	
		solar storm	
CONCAUSAL	ANTHROPOGENIC + NATURAL		

Fig. 1.3b
New classification of catastrophes and disasters, by the Author.

worldwide with dismaying frequency.

Most flood devastations are due to humans' recklessness rather than his desire and need to live close to water. People are not particularly aware that to backfill and build on floodplains aggravate the problem, as the land is not able to absorb the same amount of water, and neither work as buffer anymore. In order to try and escape flood-related issues, many governments provide insurances, instead of affording flood-resistant or -adaptive structures. Ambitious engineering efforts are the result of long-term strategy to mitigate inevitable floods. Advancements in computer modelling are increasing the accuracy of events predictions and structures calculation by Authorities, Agencies and engineering groups. Talking about disasters, one enters another temporal scale (Fig. 1.4). As a large piece of community is involved, time, space and costs alike are wider than usual: time is irregularly expanded, space is fragmented, and costs are non-linear.

In the light of these considerations, it is correct to talk about sustainability of political choices.[15] Policies more than insurances shall shape risk management. In fact, while insurances let disasters happen again in future, right policies avoid catastrophic events to become disasters. Insurances regard the individual, while policies are about the entire society. Indeed, they simply postpone another critical event, without any sort of protection for people and communities; they are patchwork quilt of a weak social system. On the other hand, policies act on the layer of prevention. Any measure taken in advance is cheaper than any recovery, and it guarantee safer places where to live. Catastrophes cannot be avoided, but strategic planning and society shall be able to not let them becoming disasters.

[15] Mihelcic J.R., et al., 2003, "Sustainability Science and Engineering: The Emergence of a New Metadiscipline". In *Environmental Science Technology*, 37 (23), pp. 5314-5324, American Chemical Society.

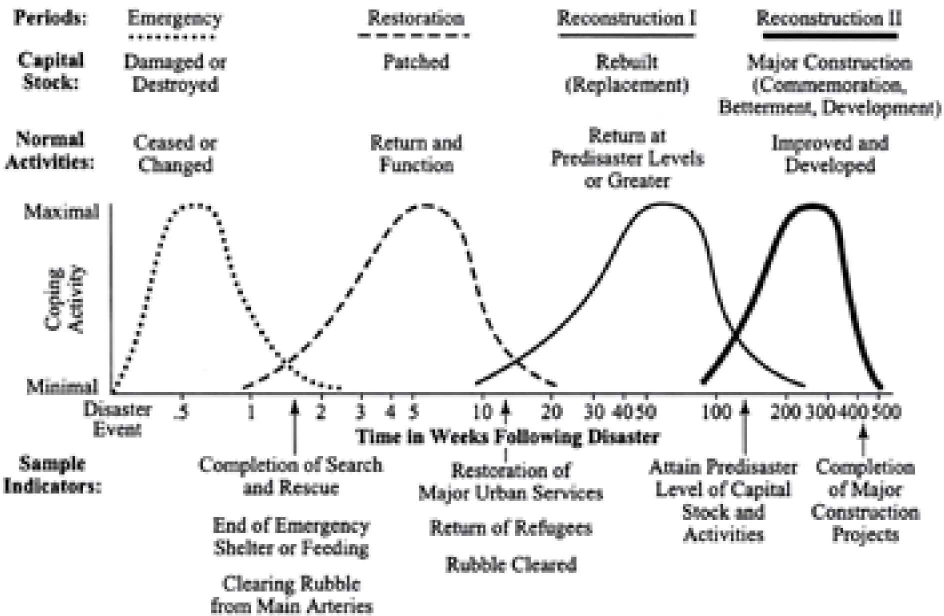


Fig. 1.4
A model of disaster recovery activity.
(Vale L.J., Campanella T.J., 2005, *The resilient city. How modern cities recover from disaster*, Oxford University Press, New York)

1 "Καὶ γὰρ ἐκείνοις πᾶσιν αἱ καταστροφαὶ τῶν δραμάτων προσδέονται θεοῦ καὶ μηχανῆς διὰ τὸ τὰς πρώτας ὑποθέσεις ψευδεῖς καὶ παραλόγους λαμβάνειν, τούς τε συγγραφέας ἀνάγκη τὸ παραπλήσιον πάσχειν καὶ ποιεῖν ἥρωάς τε καὶ θεοὺς ἐπιφαινομένους, ἐπειδὰν τὰς ἀρχὰς ἀπιθάνους καὶ ψευδεῖς ὑποστήσωνται."

Ἱστορίαι (Histories, 3.48.8-9)

[3:48.1 For could a more irrational proceeding on the part of a general be imagined than that of Hannibal, if, when in command of so numerous an army, on whom the success of his expedition entirely depended, he allowed himself to remain in ignorance of the roads, the lie of the country, the route to be taken, and the people to which it led, and above all as to the practicability of what he was undertaking to do? They, in fact, represent Hannibal, when at the height of his expectation of success, doing what those would hardly do who have utterly failed and have been reduced to despair,—that is, to entrust themselves and their forces to an unknown country. And so, too, what they say about the desolation of the district, and its precipitous and inaccessible character, only serves to bring their untrustworthiness into clearer light. For first, they pass over the fact that the Celts of the Rhone valley had on several occasions before Hannibal came, and that in very recent times, crossed the Alps with large forces, and fought battles with the Romans in alliance with the Celts of the valley of the Padus, as I have already stated. And secondly, they are unaware of the fact that a very numerous tribe of people inhabit the Alps. Accordingly in their ignorance of these facts they take refuge in the assertion that a hero showed Hannibal the way.] They are, in fact, in the same case as tragedians, who, beginning with an improbable and impossible plot, are obliged to bring in a *deus ex machina* to solve the difficulty and end the play. The absurd premises of these historians naturally require some such supernatural agency to help them out of the difficulty: an absurd beginning could only have an absurd ending.

2 Bible (Revelation 12:7-9) Then war broke out in heaven. Michael and his angels fought against the dragon, and the dragon and his angels fought back. 8 But he was not strong enough, and they lost their place in heaven. The great dragon was hurled down—that ancient serpent called the devil, or Satan, who leads the whole world astray. He was hurled to the earth, and his angels with him. (Revelation 20:1-3) And I saw an angel coming down out of heaven, having the key to the Abyss and holding in his hand a great chain. 2 He seized the dragon, that ancient serpent, who is the devil, or Satan, and bound him for

a thousand years. 3 He threw him into the Abyss, and locked and sealed it over him, to keep him from deceiving the nations anymore until the thousand years were ended. After that, he must be set free for a short time. (Isaiah 14:12-15) How you have fallen from heaven, morning star, son of the dawn! You have been cast down to the earth, you who once laid low the nations! You said in your heart, "I will ascend to the heavens; I will raise my throne above the stars of God; I will sit enthroned on the mount of assembly, on the utmost heights of Mount Zaphon. I will ascend above the tops of the clouds; I will make myself like the Most High." But you are brought down to the realm of the dead, to the depths of the pit.

[8] The idea of *Gestalt* has its roots in theories by D. Hume, J. W. von Goethe, I. Kant, D. Hartley, and E. Mach. The first phase belongs to the last decade of the 19th century and is headquartered at the Universities of Wien and Graz, and München. (H. Cornelius); the second, initiated by M. Wertheimer in Berlin and then in Frankfurt and the U.S., has had its greatest exponents in W. Köhler, K. Koffka, W. Metzger and K. Lewin.

[15] - John Pike. "Japan Tsunami Damage Cost Could Top $300 Billion". Retrieved 15 November 2014; - "FACTBOX-China's recent measures to spur growth". News.alibaba.com. November 6, 2008. Retrieved November 2, 2009; - Great Hanshin earthquake http://www.rff.org/Documents/RFF-BCK-Cohen-DHCosts.pdf; - "Nuclear industry: Face your demons - towards full liability for nuclear power plant operators" (PDF). Friends of the Earth Europe. Retrieved 15 November 2014; - "The World Bank Supports Thailand's Post-Floods Recovery Effort". World Bank. 13 December 2011. Retrieved 25 January 2012: - "New Zealand Earthquake Report – 22 February 2011 at 12:51 p.m. (NZDT)". GeoNet. Earthquake Commission and GNS Science. 22 February 2011. Retrieved 22 February 2011; - Pasch (2008-09-07). "Hurricane Ike Discussion Twenty-Eight". NHC. Retrieved 2008-09-08; - "Pbs.org." Great wall across the Yangtze. Retrieved on 2009-08-01; - "Biscayne National Park Plaque Commemorates 10th Anniversary of Hurricane Andrew". National Weather Service. 2002. Retrieved 24 August 2011; - 1994 Northridge earthquake. http://earthquake.usgs.gov/earthquakes/states/events/1994_01_17.php; - "Costs beyond measure". Retrieved 15 November 2014; - Camp, Vic. "How Volcanoes Work – the Nevado del Ruiz eruption". SDSU Department of Geological Sciences. San Diego State University. Retrieved July 20, 2010; - http://www2.canada.com/edmontonjournal/news/business/story.html?id=b089dd83-4d5a-401e-bbb9-2a10c51593e2; - "Slave Lake fires 2nd costliest insured disaster". CTV News. 2011-07-05. Retrieved 2011-07-05.

Risk within communities

A matter of probability 1.2.1

The term «risk», that literally means a situation involving exposure to danger, has a very uncertain origin. It is supposed to come from the medieval Latin «*riscus*» and «*risigus*», deriving itself from the Latin «rĕsĕcas» that means «to cut» (split waves backwards [Canello], danger of colliding against the rocks [Diez]); or from greek «ῥιζικόν», *rhizikón*, that means 'radical'; or from the Arabic «رزق», *rizq*, that means 'what comes from God and what must be taken advantage of'. The notion of risk has arisen, with modernity, in the field of sailing and trade, with the first contracts *'ad risicum et fortuna'* or *'pro securitate et risico'*. Whatever the origin is, all the meanings highlight the possibility of men causing damage, even the sacrifice of lives. In common language we are accustomed to associate with «risk» the generic notion of danger, sometimes even using one as a synonym of the other. But danger usually does not depend on us, while risk is a matter of our choices, always connected to human decisions, and therefore we can often evaluate it. It is not possible to measure the degree of risk in an absolute sense: it does not exist as objective reality, because it is not a physical feature of it.

Therefore, risk is a category of thought that makes a particular range of choices, events and concrete phenomena representable and manipulable, and it 'presuppose[s] human decisions' (U.Beck, 2006). Risk is not a feature of the 'outside material' world (B.Latour et al, 2010), which cannot be determined without undergoing any transformation. It is indeed a crucial concept in the daily choices of individuals who make decisions that bring greater benefits. Risk replaces the danger, but does not eliminate it; danger tests us and through the perception of risk we try to measure danger, to limit and circumscribe it according to a calculation of indeterminacy. These evaluations place it in the context of possible events, that can occur according to a probability rate that serves as a measure of risk. The 'Principle of Safety' *(Das Prinzip Sicherheit)* was born from risk analysis, meant as a rational measurement, which contributed to shaping modern ideology, fostering the contemporary illusion of the total elimination of risk (Sofsky 2005).

A natural hazard that is not going to occur has risk that tends to zero. It would be incorrect to say 'equal to zero', as there could always be an unpredicted event that happens. 'Low-probability, high-impact events that are almost impossible to forecast—we call them Black Swan events—are increasingly dominating the environment'.[1] Certainty is only an illusion. But our calculations and predictions about risk are shaping our assessments. A natural hazard that is certain to occur has probability equal to one. Thus, one can say again that the situation is not 'at-risk', as the event will surely happen. Although the two ends of the scale are not 'at-risk', their manifestations provoke two very different kinds of preventions and actions.

When related to a catastrophic event, the risk determines the amplification or the decrease of physical effects of the impact on the community, i.e. the magnitude of the disaster. Each socio-cultural system is characterised by its own degree of vulnerability, which determines the severity of the disaster, in connection with the intensity of the physical agent. The vulnerability of a society is defined by the possibility of its being under attack or harmed by an external catalyst. We shall define it as the «impact agent», which takes shape in relation to resilience and adaptation, and which means the survival of a man-made environment.

All in all we can assert that the relationship between the magnitude of disaster «D», the impact agent «I» and the system vulnerability «V», is

$$D = I \cdot V \quad \text{(i)}.$$

This formula highlights the direct proportionality between the disaster and societal vulnerability. In this study we shall consider natural phenomena as the impact agent; thus when the usual balance between local community (human beings and the environment he has created) and natural

[1] Taleb N.N., Goldstein D.G., Spitznagel M.W., 2009, *The Six Mistakes Executives Make in Risk Management*, https://hbr.org.

[i] Ligi G., 2009, *Antropologia dei disastri*, Editori Laterza, Bari, pg. 18.

environment is broken due to any catastrophic event, the disaster occurs. The lower the social vulnerability, the lower the disastrous effects and consequentially, the social aftermaths. In the event of a disaster, the sense of community is enhanced, and it is concretised in the "community of sentiment" (A.Appadurai, 1990) that forms the microcosms based on the place and the time of that particular community. For this reason, the attempts of recreating the conditions of a *status quo* unbinding urban structures and socio-anthropological features will always fail. The magnitude of a disaster is valued taking into account damages, losses and emergency operations: number of deaths, number of injured people, injury severity, dwellings and goods damaged, environmental impact, displaced people, homeless, disruption to economy (volume of production lost), volume of manpower, days employed for emergency operation, etc.

The probability a catastrophic event takes place influences—without determining it—the awareness of a community to a precise phenomenon for which programs and plans are thought and designed. In particular, the term «vulnerability» can be specified in three components. These are: the incorrect planning and the negligence in applying rules «h_e» (the hazard enhancement); the effective planning and the whole safety devices adopted «h_m» (the hazard mitigation and adaptation); and the local risk perception «r_p». After having considered these aspects we can complete the previous formula as follows:

$$D = I \cdot [h_e - h_m \pm r_p]$$ (ii).

That means, the total vulnerability depends on the conditions amplifying the risk, and on the infrastructural mechanisms reducing it. These are influenced by the risk perception according to the level of awareness and training held by the population (Alexander, 1993). The planning factors «$h_{e,m}$» are also highly influenced by the distribution of the population and the socio-cultural attitudes, i.e. by the disposition of governments' choices and laws. This is the main reason for considering vulnerability under a dynamist perspective, since it is remarkably variable in time, due to political actions that can increase or decrease its level and hence the degree of a disaster.

There has certainly been no catastrophe on our planet in the last four

[ii] Ligi G., 2009, *Antropologia dei disastri*, Editori Laterza, Bari, pp. 75, 104.

billion years[4] able to provoke a disaster sufficiently devastating to interfere with the whole human species, and the development of life. Thus, the likelihood of there being one in future solely related to the mechanics of the Universe or the Earth itself is in extremely unlikely, even though the total amount and the magnitude of catastrophes and metamorphoses are increasing both in the natural and the anthropogenic environment. The calculation of probability estimates the possibility of occurrence of an event or an events series. Probabilistic methods follow the law of large numbers, which guarantees stable long-term results for the averages of random and independent events. A probability forecast requires a significant amount of data concerning past events, in order to establish a valid pattern of occurrence. Probability «P» can be related to risk «R» and disaster «D», according to the formula

$$R = D \cdot P$$ (iii),

meaning that the level of risk grows when the probability of an event occuring increases, or the magnitude of a disaster—thus the losses—multiplies, or when the two factors are combined. As a consequence of this consideration, we can develop the previous formula once more, as follows:

$$R/P = I \cdot [\, h_e - h_m \pm r_p \,]$$ (iv), so

$$R = P \cdot I \cdot [\, h_e - h_m \pm r_p \,]$$ (v).

The risk is thus directly proportional to the probability of a natural phenomena occuring, the impact agent and the system vulnerability. The inability to lower the probability or the impact agent (at least not directly as a physical event), means that the only way to decrease the level of risk for a community is to intervene within the factors of the systems' vulnerability i.e., hazard mitigation and adaptation, and local risk perception.

Most typologies of risk need wide and particular assessment, as their correct formulation helps stakeholders and decision-makers to evaluate subsequent analysis and vital actions. As important as the identification

[4] Asimov I., 1980, *A Choice of Catastrophes. The disasters that threaten our world*, Hutchinson & Co. Ltd, London

[iii] Ligi G., 2009, *Antropologia dei disastri*, Editori Laterza, Bari, p. 138.

[iv] By the author.

[v] By the author.

of hazards, any specific risk must be prioritised in relation to other risks. This determines a specific hierarchy of actions, which means to discern systems' complexity, and the likely impacts and aftermaths.

Risk is regarded spatially and temporally, as it is part of specific features based on an historical period, its environment and society. So, the earliest need is to establish what and to whom it is happening, in a specific territory in a likely moment. Water management decisions—just like any other risk management—come straight from correct assessment after having formulated the main risks. The formulation of the problematics raise mainly from stakeholders, who help to make more effective and pragmatic decisions. Therefore, to recognise whether to involve the public in the decision-making process is a step connected to the methodology of the proposals, and their feasibility.

Identifying the source of a hazard, the way it occurs, its possible aftermaths, and the receptors at risk, it is possible to develop models of relationships between these entities. This process helps in the understanding of what should or should not be analysed in more depth, and in the prioritisation of procedures, and the risk itself for further actions. Moreover, it facilitates the adequate allocation of resources.

People's behaviour 1.2.2

attitude - behaviour gap *The frequently observed lack of correspondence between attitude and behavior led to acknowledge that although having strong goal intentions is a necessary prerequisite, it is often not sufficient for goal-directed behavior.*

Now let us consider the general awareness of risk, and the concrete use of risk evaluation within social contexts through the risk assessment. The main source of massive information is the media, which can significantly affect knowledge and perception of a particular issue. But the main concern is the '**attitude-behaviour**'[8] **gap** (P.Sheeran, 2002) that is, a lack of actions after being aware of a specific risk. The way of coping with this gap has often be considered to provide people more information, but this strategy has produced modest behavioural changes, as it is not diffused on a local scale. Since any form of community engagement facilitates people's behavioural change, the goal should be the active variation of the natural and built environment by local authorities, so that the mitigation and adaptation goals are shown to the community. It is fundamentally an inverse process of acknowledgment that takes advantage of pilot cases in

[8] Sheeran P., 2002, Intention-behavior relations: A conceptual and empirical review. In Hewstone M. Stroebe W. (Eds.), *European Review of Social Psychology*, Vol. 12, pp. 1–36, Chichester, England: Wiley.

order to increase people's awareness. Thus, a combined influence sways behaviours, since inputs are both experiential and notional.

The complexity of climate change—in the sense that its various features make it difficult to be communicated—is made even more complicated by prior belief. It is proved that quite often a disastrous event does not change communities' attitudes, even though the likelihood that the hazard will occur again is extremely high. Increasing knowledge does not necessarily lead to an increasing concern: cultural background and scepticism are frequently much stronger than the chance of change. (That is the case of many flooded or hurricane-hit communities.) People are also confused in understanding relationships between different complex events, like the ones between climate change and flooding. That is due to misconceptions about the relative weight of various causes that contribute to the overall phenomenon. This uncertain condition contributes to a widespread 'wait and see'[9] attitude (C.Xiang, 2011), which unfortunately is not just a feature of individuals, but it also affects authorities.

The temporal and spatial distance that separates climate change from the average-person is generally caused by both a difficulty in visualising future periods and a general sense of optimism, which involves non-tangible topics. Since climate change cannot be experienced directly, a primal risk response fails to be activated. People often consider this issue as something that is affecting 'others'. But the rapid increase of the magnitude of catastrophic events is raising the number of these 'others', and feelings of fear and worry are affecting more communities and individuals. These intense motivators are guiding behavioural change through the so-called 'prospective and retrospective'[10] consequence-based emotions (G.Böhm, 2003). Direct experience should immediately influence risk perception and behaviours, so that threats can be immediately mitigated. But this is not always so, as we can frequently observe a dissociation between information and experience, and the ability to observe them in order to lower the level of risk in their own environment and on a larger scale. As stated by I.L.Janis (1967), moderate levels of fear are more persuasive than the higher ones, and in this perspective the fear-appeal approach in media

9 Xiang C., 2011, Why do people misunderstand climate change? Heuristics, mental models and ontological assumptions. In *Climatic Change*, Sep2011, Vol. 108 Issue 1/2, p31, Springer Science + Business Media.

10 Böhm G., 2003, *Emotional Reactions to Environmental Risks: Consequentialist versus Ethical Evaluation*, Journal of Environmental Psychology.

communication has been used and gained some results[11] (mostly in the short-term period).

Behaviours can also be altered by normative systems, through the conformation of the group. In fact, people tend to modify their habits when they perceive benefits from a known righteous case. Social norms then become moral ones over time, as the values are internalised, playing a central role in environmental behaviours. At the same time people must be aware about measures—and economic efforts—to mitigate risk. Policies and, consequentially, plans are based on risk assessment, whose information leads to decisions on how to protect communities, depending on the level of risk.

Risk assessment is the process of evaluating potential **hazards** and analysing what could happen if a hazard has occured (Fig. 1.5). It depends on the hazard assessment, which is based on geophysical conditions, historical datasets, and simulations and projections derived from theoretical studies and model outcomes. There are a number of hazards to consider, and for each one there are many likely scenarios that could take place depending on timing, magnitude and location of the catastrophic event. The assessment itself typically involves four stages: (A) identifying the hazard(s); (B) assessing the potential consequences; (C) assessing the probability of the consequences; and (D) characterising the risk and uncertainty.[12]

ﺏﻱﻩﺭﺕ *from Arabic az-zahr, from from Persian zār or Turkish zar [the dice], to mean the chance.*

The identification of the hazards has a crucial relevance on the scope of global assessment. One typical hurdle is to consider collateral hazards that may also arise: they need accurate consideration during problem formulation to render an overall risk assessment. The potential aftermaths related to any hazard are inherent to that hazard, and within the spatial and temporal scale of its likely consequences. After having prioritised potential impacts, and their qualitative and quantitative characterisation, it is important to evaluate the likelihood of the initiating event happening, the probability of vulnerability caused by the hazard, and the probability of the receptors being damaged by the hazard. Data from agencies is very helpful in defining trajectories and probabilities, but it is quite difficult for rare event evaluations. It is therefore highly recommended to consider data relevance to the problem. Then, risk characterisation pulls together

11 Janis I.L., 1967, Effects of fear arousal on attitude change: Recent developments in theory and experimental research. In Berkowitz, L. (ed.), *Advances in experimental Social Psychology*, Vol. 3, pp. 166–224, San Diego, CA: Academic Press.

12 Gormley Á. et al., 2011, *Guidelines for Environmental Risk Assessment and Management*, Crown Copyright.

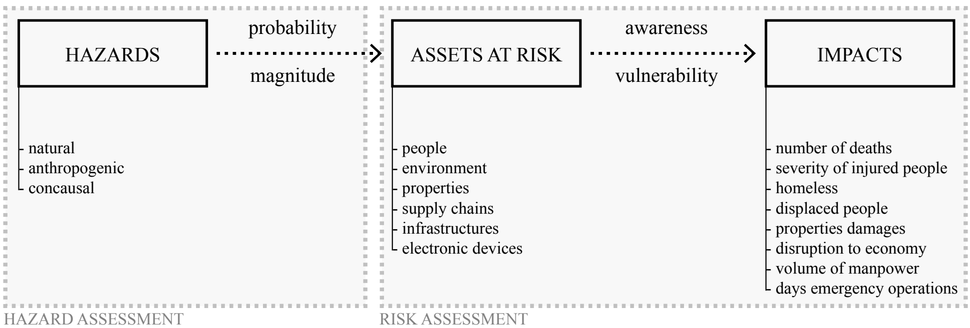


Fig. 1.5
Hazard and Risk Assessment Process diagram, by the Author.

all the information, determining the qualitative and quantitative "likelihood of occurrence of the known and potentially adverse effects that an activity or agent presents to a given receptor under defined exposure conditions, along with acknowledging the assumptions and uncertainties" (OECD, 2011). Unacceptable levels of risk require strategic planning, targeted risk management, and operative actions to reduce them to tolerable levels of residual risk.

Risk assessment is a decision-making process that provides a holistic method for developing sustainable policies and interventions to lower the impact of natural and anthropogenic hazards, and consequential losses. Five steps usually compose the mitigation path: (1) community exposure; (2) existing risk management techniques analysis; (3) implementation of risk management techniques; (4) plans and intervention within the natural and built environment; (5) monitoring results. Social questions such as the meaning of risk must not be addressed separately to the assessment aimed to evaluate the magnitude of risk.

Societies have a long history in managing the impacts of environmental catastrophes; for instance, expanded rainwater harvesting, water storage and re-use, settlement relocations, etc. However, continuous upgrading is necessary to improve adaptation measures, in order to tackle hazard variations. This is particularly true regarding climate change, for which mitigation measures should be undertaken over the next few years, as other stresses are aggravating the level of risk. While the term «adaptation» refers to systems and technologies built to directly combat the effects of a catastrophe—i.e. the catastrophe becoming a disaster—, «mitigation» includes any sector that can contribute in lowering the negative emission of the source that causes a catastrophic event, such as reduction in the emission of carbon dioxide. Moreover, mitigation has an embedded implication that cannot be provided by a single technology, and it relies on regulations, such as those produced by the Intergovernmental Panel on Climate Change (**IPCC**). Thus, adaptation and mitigation are complementary sides of a multi-scale reality. "In several sectors, climate response options can be implemented to realise synergies and avoid conflicts with other areas of sustainable development. Decisions about macroeconomic and other non-climate policies can significantly affect emissions, adaptive capacity and vulnerability.[13]" (IPCC, 2007)

IPCC *was established by the United Nations Environment Programme and the World Meteorological Organization in 1988 to provide the world with a scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts.*

The costs of actions caused by both mitigation and adaptation have to be analysed in comparison with the costs of procrastination or inaction.

[13] IPCC Fourth Assessment Report: Climate Change 2007.

For example, the Federal Emergency Management Agency (FEMA) has averagely calculated that for each dollar not invested in mitigation and adaptation measures, four dollars would be needed for the aftermath.[14] Mitigation diminishes vulnerability by reducing the probability that event magnitude increases over time, whereas adaptation reduces the effects of an event on the environment. Even though countries with fertile economies have greater mitigation potentials compared to poorer ones, the effects of a disaster in non-resilient societies are exactly the same. The difference is the post-disaster management, since it is often part of a structured national Agency.

As richer countries have higher gas emissions, they are affecting global change more substantially than the poorer, and thus amplifying not just their own vulnerability but also the vulnerability of less well off countries. They are therefore asked to contribute significantly more in reducing the impacts of natural hazards, which must be combined with infrastructural and structural strategies to reduce negative aftermath and losses within communities. Information about the causes of global warming can help create a better understanding of appropriate response behaviours (S. van der Linden, 2014). Hazard maps—showing spatial and temporal variation of a physical phenomenon—shall be used to form maps of risk, in order to guide planning approaches and growth of cities both now and in the future.

A society in which local and global risk awareness is growing changes its pillars, and its perspectives with them. The very nature of that society is democracy and modernity, as there is no distinction between rich and poor, male and female, educated and under-educated people, when a disaster takes place.

[14] Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities, Multihazard Mitigation Council of the National Institute of Building Sciences, December 2005.

Global warming and the spook of ‘climate change’

Shifting ‘the end’ 1.3.1

«The end of the world» and «the very last chance» speeches have been in vogue since ancient history, revolving around religion as well as politics. Considering their anxiety about the end of the world right before 1000 AD, lords and clergy of the time waited for the interpretation of phenomena by bishops and monks. Thus, it was not just the commonalty to believe in such a conviction (Capitani and Miethke, 1990). Since every sign was potentially eschatological, the fear was quite widespread in Europe, but not specifically located. Despite warnings from some monks, calculations for the time of Judgment were on-going. “Thus far, all of the dates set for the end of the world have passed without incident. But the prophets have often had an explanation for their apparent failures”.[1]

One century later, people are still calculating when ‘the end of the world’ will likely occur. Nowadays one of these ‘ends’ concerns the environment, specifically global warming (often simplified as ‘climate change’). Low levels of concern and denial have let the matter pass by, and this awarelessness blinds our understanding that the end of the world might already have happened. Humankind cannot go backwards now. There is no way to repair what we have been doing over the last hundred years. Deniers assert “that one can never directly prove the human causes of global warming, just as I never prove that this bullet you fire into my head will kill me.”[2]

1 Hawking S., 1993, *Black Holes and Baby Universes*, Bantam Books, London.

2 Morton T., 2013, *Hyperobjects: Philosophy and Ecology After the End of the World*, University of Minnesota Press.

Global warming is not a static object, because its manifestations are not inactive, but interrelated and often tied to people's activities. Natural hazards, multiplied by global warming and humans' lack of knowledge and incompetence, determines the magnitude of a disaster, or—hopefully—just a catastrophe. For many global phenomena the point of no return has already passed, and there is no way of adopting mitigative actions. What people can do now is to adapt their standards, habits, and behaviours to a new condition.

There is a wide debate over the dichotomy between mitigation and adaptation. Mitigation is any measure adopted to permanently eliminate or reduce long-term risks and hazards. The International Panel on Climate Change defines mitigation as "an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases." Mitigation involves reducing the magnitude of global warming itself, and is carried out through emissions reduction—dealing with the phenomena at the very source—, and geo-engineering—offsetting the effects of greenhouse gas emissions. On the other hand, adaptation refers to the ability of any system to conform itself to changes, so that probable damages are avoided or reduced. It does not usually deal with the underlying cause of the hazards. The IPCC defines adaptation as the "adjustment in natural or human systems in response to actual or expected climatic *stimuli* or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation."[3]

As a matter of fact, the decision between adaptation and mitigation measures is a false choice: our ecosystem needs both, but their effects have different time scales. Global warming has been increasing due to the greenhouse gasses we have already emitted. Nobody can mitigate that change. So, what people can do is to adapt their lives and various systems to at least accommodate that variation. Of course mitigation is crucial to avoid future increase, but it is definitely not retroactive.

Global phenomena could only be understood when their manifestations are related, and not considered as single entities. That is, there is no centre of catastrophic events or phenomena, and local communities are not the centres of them either. They are not for two main reasons: a. there is no one community affected by a catastrophic event alone; b. they may not be the cause of the catastrophic event, as other communities' actions are involved from a distance. For instance, in Berkeley, in 2011, the radia-

[3] http://www.ipcc.ch/ipccreports/tar/vol4/index.php?idp=204

tion level in water reached the peak of one hundred and eighty-one times higher than normal, after the accident at Fukushima's reactor. Though, since things never coincide with their phenomena[4], we shall try and understand what global warming—a **nonlocal** and atemporal entity—really is and how it manifests in the real world.

nonlocality *is a concept born in the 19th century to describe an object that can move without having been physically touched (James Clerk Maxwell). In quantum mechanics the same term indicates the ability of objects to instantaneously know about each other's state, no matter how large the distance is (beyond the speed of light though).*

As the sun's rays reach the Earth's surface some of them are absorbed and reemitted as heat. Greenhouse gasses such as water vapour and carbon dioxide absorb and reradiate some of this heat. Increased amount of greenhouse gasses in the atmosphere mean more heat is tracked, warming the Earth. Human activities, especially the burning of fossil fuels have increased the concentration of carbon dioxide by 40% during last 200 years, mainly since 1900. The global average surface temperature has increased by 0.8° C over that time. Other changes to the climate in recent decades can be seen in the warming of the oceans, a rise of sea level, decrease in snow and ice cover in the northern hemisphere, and the declining sea ice in the Arctic. If emissions continue unchecked then further warming of 2.6°C to 4.8°C would be expected by the end of the 21st century. Even with the lower prediction, this would have serious implications for human societies, and the natural world.

(For those who deny the effects of global warming, or those who define themselves 'agnostic', it should simply be considered that our cities are often at risk of flood, and at risk of phenomena related to flood events. So, even though one would not consider global warming as primary cause of flooding magnitude, he should ascertain that water management ought to assume a crucial role in the strategic planning of our active cities.)

Nobody can ever directly experience global warming. Nevertheless, it affects you no matter where you are in the globe. It is very hard to be seen, as it is widely distributed across the biosphere, but it is real. Many parameters like surface temperature, atmospheric water vapour, severe events (magnitude of catastrophes), sea level, etc. can be identified as indicators of global warming. Many parameters like surface temperature, atmospheric water vapour, severe events, sea level, etc. can be identified as indicators of climate change. The evaluation of the Fourth Assessment Report[5] (AR4, Climate Change 2007) classified a number of them based on three areas of indicators: temperature, hydrological, others.

4 Kant I., 2007 (1781), *Critique of Pure Reason*, Penguin Classic, London.

5 Pachauri R.K., Reisinger A. (eds.), 2011, *Fourth Assessment Report of the Intergovermental Panel on Climate Change*, IPCC, Geneva, Switzerland.

- Temperature: cooling stratospheric temperature, warming from the surface through much of the troposphere, rising global average near surface temperature, warming of sea surface temperatures, more frequent warm days and nights, fewer cold days and nights, reductions in the number of frost days, decreasing snow cover in most regions, degrading permafrost in areal extent and thickness, shrinking annual average, arctic sea ice extent, widespread glacier retreat, changes in ice sheets in Greenland and Antarctica, warming throughout much of the worlds ocean, increasing rates of global mean sea level rise;
- Hydrogeological: changes in cloud cover, increasing tropospheric water vapour, increasing surface humidity, large scale precipitation changes, increase in the number of heavy precipitation events, changes in ocean salinity;
- Others: changes in winter polar vortex strength, long-term changes in the large-scale atmospheric circulation, including a pole ward shift of jet streams, increasing concentration of CO¬ and other greenhouse gases from human activities, changes in aerosol burden and ozone concentrations, acidification of the oceans.[6]

Naturally, the one that most affects the increase of flooding is the rise of the mean global sea level. This has been evaluated for more than one hundred and fifty years with tide gauges, and from the late 1980s with satellite radar altimeters. The gauge system recorded that the average rate of global MSL raised 1.7 ± 0.2 mm per year, but since the early 1990s the rate increased to 3.2 ± 0.4 mm per year (Church and White, 2011). The main causes are ocean expansion and ice formations melting. The first one is related to a simple physical process that concerns the very nature of water: due to the increasing temperature, molecules start moving faster provoking volume expansion. The second one is related to glaciers shrinking and sea ice losses—this trend increased since 1978 and had its peak in 2012, when the ice extent was 49% lower than 1978. Sea ice has been thinning much faster than most of the climate model predictions. It has been happening to the Greenland and Antarctica ice sheets from the 1990s and the greatest mass losses have been registered in Patagonia, Alaska, northwest USA, southwest Canada, the European Alps and the Arctic (IPCC, Climate Change 2013). Glaciers and other ice formations logically melt back

6 *Climate Change 2013: The physical science basis*, IPCC Working Group | Contribution to AR5.

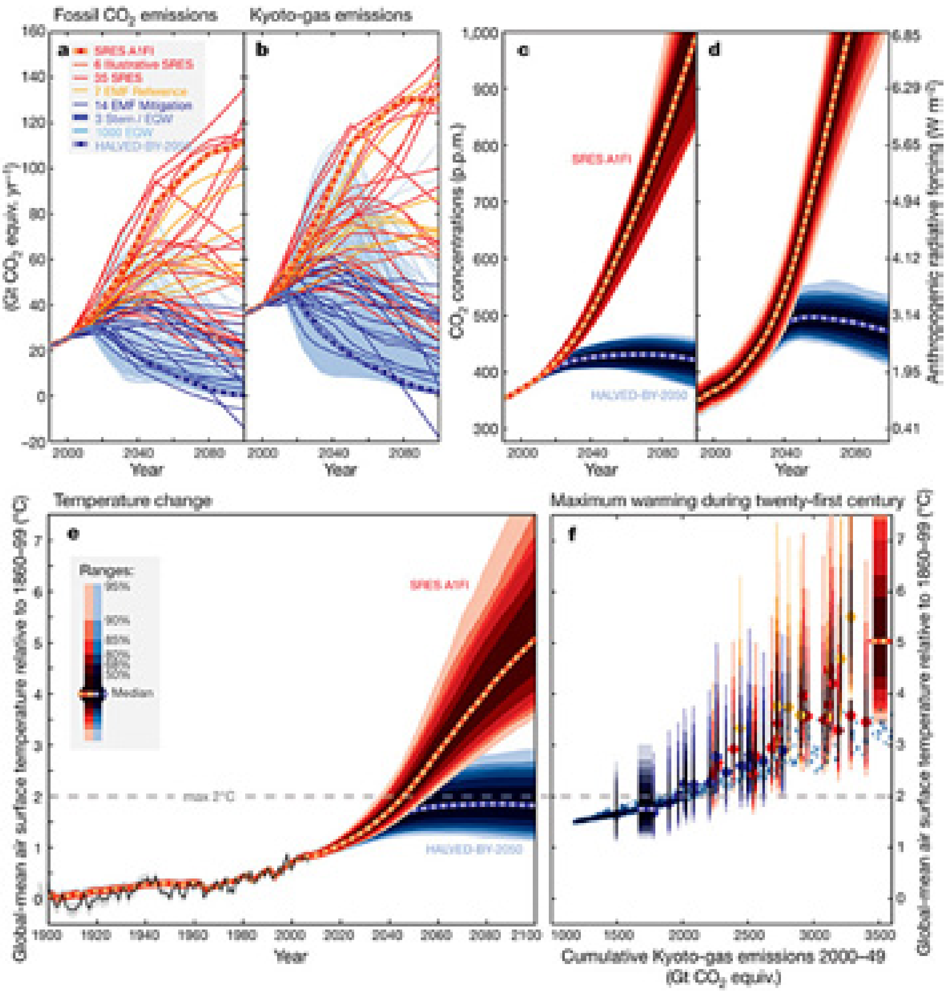


Fig. 1.6

Emissions, concentrations and twenty-first century global-mean temperatures.

a, Fossil CO_2 emissions for IPCC SRES, EMF-21 scenarios and a selection of equal quantile walk (EQW) pathways analysed here; b, GHGs, as controlled under the Kyoto Protocol; c, median projections and uncertainties based on our illustrative default case for atmospheric CO_2 concentrations for the high SRES A1FI and the low HALVED-BY-2050 scenario, which halves 1990 global Kyoto-gas emissions by 2050; d, total anthropogenic radiative forcing; e, surface air global-mean temperature; f, maximum temperature during the twenty-first century versus cumulative Kyoto-gas emissions for 2000–49. Colour range shown in e also applies to c, d and f.

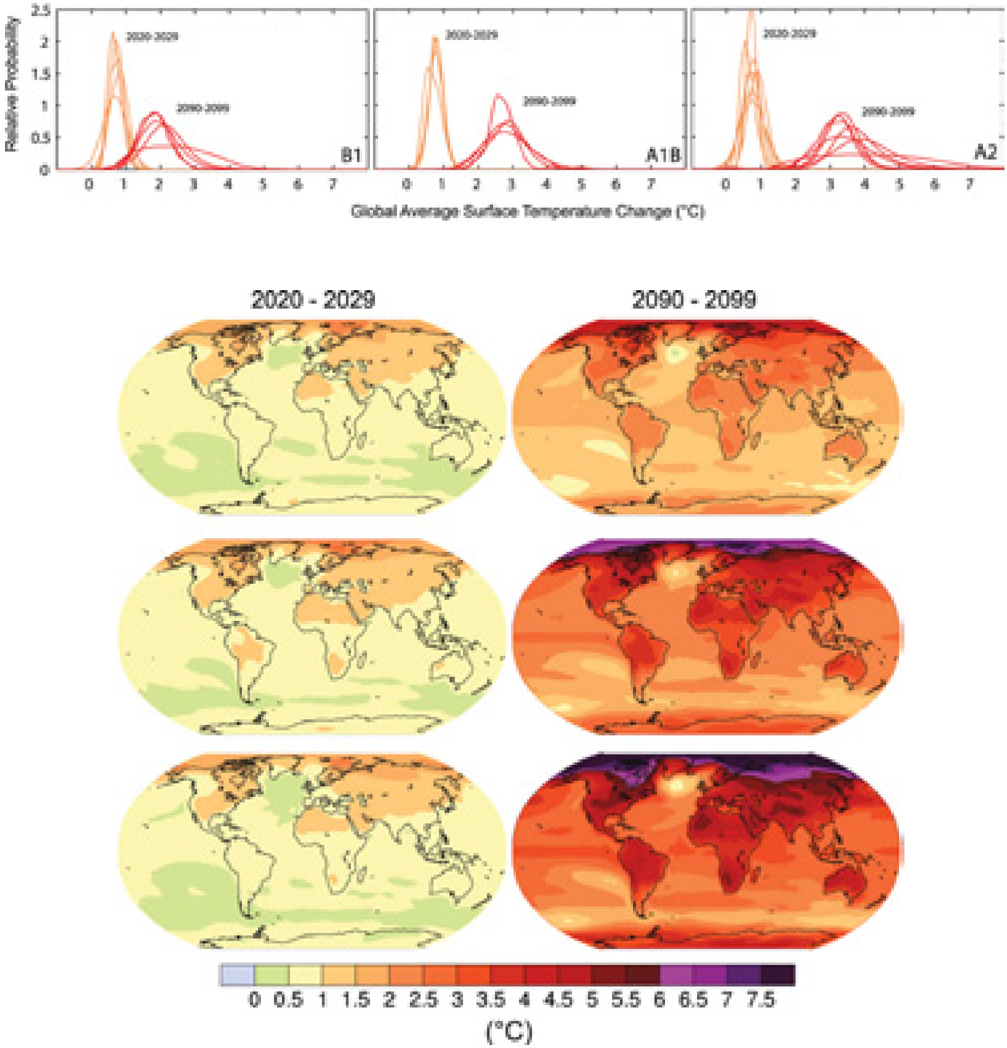


Fig. 1.7
Surface Temperature Change (IPCC).

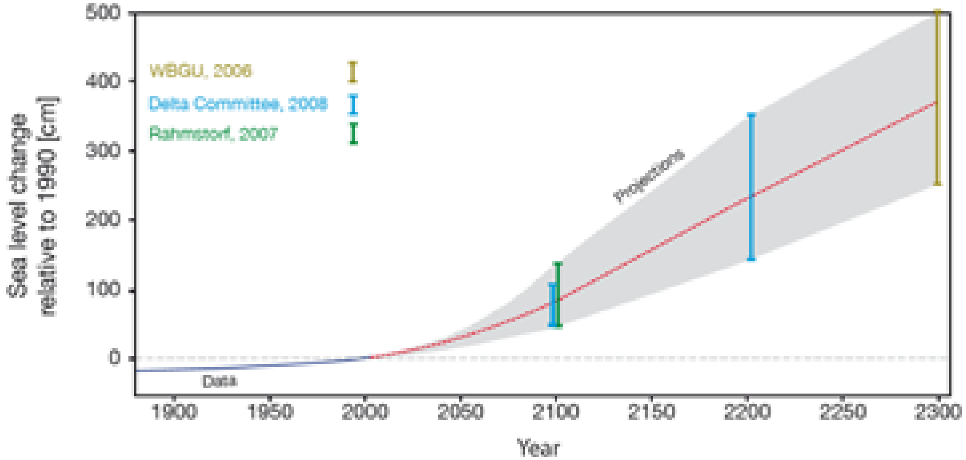


Fig. 1.8
Recent projections of future sea level rise.
Historical data from Church and White (2006). Future projections are from Rahmstorf (2007) and WBGU (2006), while those projections represented here as 'Delta Committee' are from Vellinga et al., (2008).
(2009 UNSW Climate Change Research Centre).

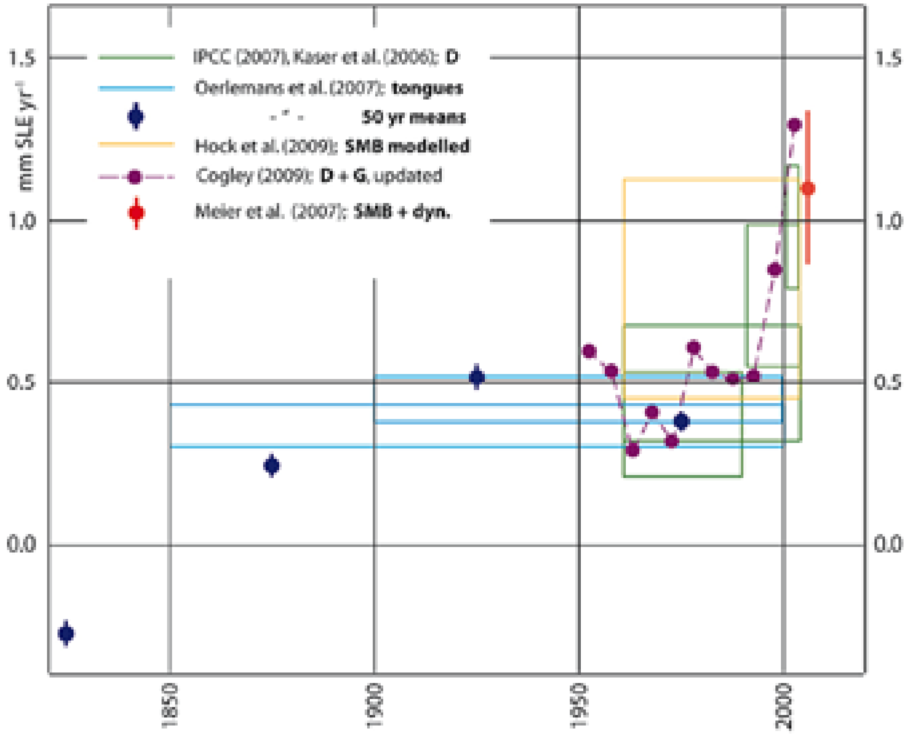


Fig. 1.9
Estimates of the contribution of glaciers and ice-caps to global change in sea-level equivalent (SLE), in millimeters SLE per year. (2009 UNSW Climate Change Research Centre).

a bit in summer time. But in the winter, snows were usually adequate to balance out the melting. Recently, global warming has increased summer melting and reduced snowfall, causing the sea level to rise. IPCC predictions speculate about the water exceeding a 1 metre (3 ft) rise by the end of the 21st century. Statistical analysis reveals that the rate of this rise is closely correlated with temperature: the warmer it gets, the faster sea level rises (Rahmstorf 2007).

There is no mitigation that could give glaciers back the melted ice, but we can try and delay the disappearance of glaciers. New predictions unveil that the mass loss of glaciers and ice caps has remarkably risen since the last decade of the 20th century (Fig. 1.7), and is now responsible for about a 1.2 millimetre rise per year on the global sea level. Present temperatures are not keeping a balance for the yearly preservation of glaciers and ice caps. Recent estimates show that adjustment to that alone will cause a mass loss equivalent to about an 18 centimetre sea level rise (Bahr et al. 2009) within this century. Estimates predict that uncontrolled global warming is likely to increment the sea level by more than 3 metres in coming centuries (Fig. 1.6), causing the loss of many coastal cities, and entire islands.

Population density in coastal areas is almost three times higher than the inner ones, and about 160 million people live less than 1 meter above sea level.[7] In the immediate future this will cause significant impacts for societies and economies, as the sea level rises. Coastal erosion, floods, ground-water contamination, and loss of coastal wetlands are the main issues to be taken into consideration for strategic planning, and water management. Some cities have been developing control and defensive systems, such as *Maeslantkering* (1991-1997), the storm surge barrier in Rotterdam; the Saint Petersburg Flood Prevention Facility Complex (1978-2011); the *Zuiderzeewerken* (1920 onward), the system of dams, land fill and water drainage works dividing *IJsselmeer* to the North Sea; and the Woolwich Reach Thames Barrier (1974-1982), preventing London from being flooded by high tides and storm surges.

[7] Allison I. et al., 2009, *The Copenhagen Diagnosis. Updating the World on the Latest Climate Science*, NSW Climate Change Research Centre, Sydeny

Vulnerabilities as main variables for strategic planning 1.3.2

The statistical increase of frequency and magnitude of floods is considered by some to be merely abnormal events that occur very few times over their entire lives; but others see this evidence as the beginning of a trend due to the effects of global warming. What is clear, though, is the degree of vulnerability of communities located near rivers and the sea, and the lack of management in trying to find a solution before—and not after—a catastrophic event. All the cities require water for their functions, and as such often proliferate along rivers, the only way to enforce the dichotomy is to consider rivers as opportunities instead of threats. The issue of flooding becomes a major concern when water flows onto an urbanised area, and the hardscape does not permeate or run the water off. During heavy rain periods and high tide days the horizontal surfaces are fully saturated, and water treatment facilities and sewerages are pushed over their limits. As a direct consequence, the water begins to fill up the closest and lowest area it comes across. The regularity of water overflowing urban areas has led some advanced societies to react to flooding, keeping people and properties safe. In the age of an overabundance of information, the attitude of confusing the quantity of data with knowledge is ascertained. In fact, only knowledge allows societies to reach final goals through a solid decision-making process.

There are numerous possible actions to consider in order to defend river banks, floodplain, and coastlines against the threat of the raising sea level. We are likely already committed to almost a 1 metre rise of global sea level by the end of the 21st century, as previously seen. The first move is to take on encroaching water by building defences such as barriers, dikes and locks, and larger works such as polders. When these actions are no longer sufficient, the next step is to let water flow through, and to build flood-proof and floating structures.

In London the first step was reached in the 1980s. The Thames Barrier was built downstream of the Isle of Dogs in response to the common floods that were affecting the city, which in 1928, 1947 and 1968—just to cite the 20th century ones—brought London to its knees. Its northern bank is in Silvertown, in the borough of Newham, and its southern one is at New Charlton, in the borough of Greenwich. There, the river width is 518 meters (1,700 ft) and 5.8 meters below ***Chart Datum***. It has been activated one hundred and seventy-nine times since its opening. Four closures were registered in the 1980s, thirty in the 1990s, seventy-five in the 2000s, and sixty-five from 2010 until March 2014. As the water level is rising, the

chart datum *or the plane of reference to which all charted depths and drying heights are related (but not other heights and elevations). It is a level so low that the tide will not frequently fall below it. Usually defined in terms of low-water level such as LAT or ISLW. Chart datum is not a horizontal surface but may be considered as such over a limited local area.*

Barrier gates will be closed more frequently (16,000£ per closure), but it is predicted that their efficiency will not be valid by around 2070. By that time the flood probability will be one to ten, while the Thames Barrier was built to protect London with an exceeding probability of about one in every one thousand years (Vaughan, 2013).

The increased risk posed by rising water levels—1:20 for more than 84 cm rising by 2100—is the main reason why a new estuary barrier has been taken into consideration as well as Thames Barrier strengthening. This appraisal takes into account only tidal predictions, as a global condition, without evaluating local factors related to rivers, canals and groundwater. The estimations are based on carbon dioxide emissions, which seem to lead to about a 3.5°C rise in mean global temperature by the end of the 21st century. Moreover, Southern England is sinking into the water at the rate of about 30,5 cm (12 inches) per century, due to tectonic phenomena.

The Barrier has to cope with two contrasting flows, the one from the tide, coming from the North Sea, and the one from the River Thames stream, coming from the west. London's defence system is designed to contrast more against tidal flood than fluvial and groundwater ones. A second Thames Barrier could be built in future to prevent potentially devastating flooding close to the estuary, and some feasibility studies have already been conducted. Yet, the new barrier that should arise at the Thames estuary will avoid the 'flood warning areas' (Environment Agency) to be flooded by the tide water coming from the sea, but fluvial floods vulnerability would not be particularly lowered. For this reason, structural interventions within urban fabric must be implemented, as a complementary process of adaptation. In doing so, the relationship between the city as a whole and its parts would not be broken: the structure of the city and the design of its organisms shall self-determine reciprocally. Furthermore, the risk of disjunction between infrastructures and the structures of the city would be avoided. As a matter of fact, the enforced flooding of the hinterland is a clear proof of this incoherence. In fact, the common strategy is to allow water flooding the less lucrative areas of London, so that the city centre is preserved. The capital city of England counts 8,308,369 inhabitants within the city (1,572.00 km^2) and 15,010,295 within the metropolitan zone (8,382.00 km^2).[8] The Thames Barrier protects around 1.25 million people living and working in the London floodplain from tidal flooding.

Only man, of all the species that have lived on the Earth, has reached a level of intelligence that has allowed him to radically modify the envi-

[8] ONS's data, Office for National Statistic, 2013.

ronment, so that his survival is secured, or at least facilitated. Thanks to that, he has, on the whole, always been able to keep the birth rate higher than the death rate. Around 6000 BC, in the second half of the Neolithic Era, the total human population was about 10 million, which is more or less the same of London's urban area; in the 8th century BC, at the time of the founding of Rome, it raised to 100 million; it reached 500 million in the 16th century, 1 billion at the beginning of the 19th century, 2 billion in the 1920s, 4 billion in the 1970s, and in 2011 the human population has reached the 7 billion mark. The rate of population increase was lower than 0.02 per cent per year over the millennia before agriculture; it reached 0.5 per cent per year in the 19th century—that means the population was doubling in 140 years. At the present rate, the world population doubling period is about 50 years. We are currently seven billion two hundred million, and the United Nations' projections are delineating three very different scenarios for the future (Fig. 1.10). The medium scenario projection assumes that the world population will not vary greatly after reaching 8.92 billion in 2050, whereas in the higher scenario, it will go from 10.63 billion in 2050 to 36.44 billion in 2300.[9] The medium scenario is the most likely, and can be compared to the newer studies[10] of members of the Club of Rome.[11] In fact, they've predicted that global population growth will slow down after the peak of 8.1 billion in 2052. This will be correlated with other factors, such as productivity decline and global **GDP** growth.

GDP, Gross Domestic Product *is the standard measure of the value of final goods and services produced by a country during a period minus the value of imports.*

So far, the exponential population growth is causing a general move towards the city. This mass migration is leading to an ascending population growth in urban and hinterland areas, and cities are expanding into the surrounding countryside. Thus, both in urban and former rural areas, rapid urbanisation is unbalancing the ecosystem. In relation to economic development, population and urban function (public and private ones) has been progressively concentrating in cities. Thus, the city centre is becoming more dense and characterised by a multifunctional mix. The direct consequence of this phenomenon is the necessity to improve transport infrastructures to accommodate the demand, making the transit system extremely complex. Not considering the vulnerability of certain areas, the disturbance is degenerating into an untenable level of risk.

9 United Nations Department of Economic and Social Affairs/Population Division, *World population to 2300*.

10 Randers J., 2012, *2052 – A Global Forecast for the Next Forty Years*, Chelsea Green Publishing.

11 It was founded in 1968 as an informal association of independent leading personalities from politics, business and science, men and women who are long-term thinkers interested in contributing in an interdisciplinary and holistic manner to a better world. (from *http://www.clubofrome.org*).

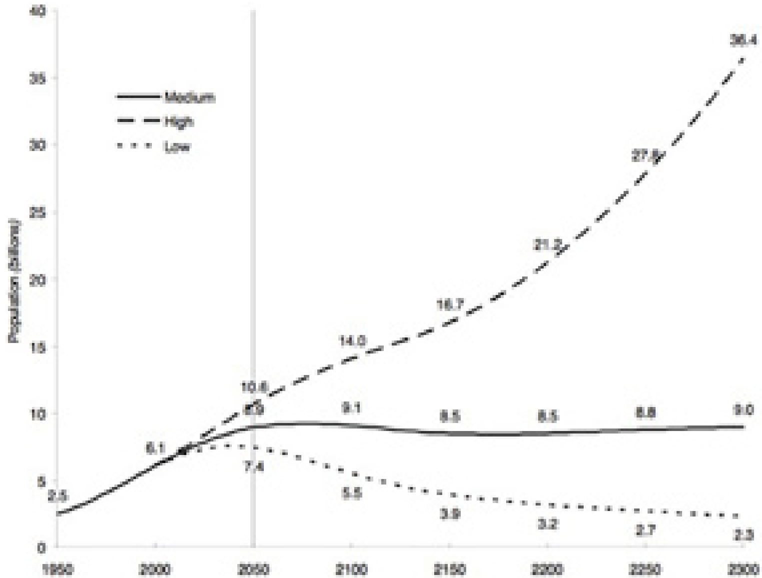


Fig. 1.10
Estimated world population: 1950-2000, and projections 2000-2300
(United Nations Department of Economic and Social Affairs/Population Division, *World population to 2300*)

'The ways in which people and societies protect themselves against and react to natural disaster says a great deal about the values and priorities of societies. Natural disasters are the consequences of encounters between nature and society, the extent of which depends on how well people have managed to adapt to dangers. [...] Natural disasters occur when a vulnerable society is exposed to a natural danger—a «hazard». This hazard may be an earthquake or a violent volcanic eruption, or longer-lasting events such as floods or drought. [...] Ideally, extreme natural phenomena do not lead to natural disasters if societies are invulnerable. But all societies are vulnerable to various degrees, depending on such factors as economy, politics, religion, and their social structure and infrastructure.[12]'

Urbanisation is a significant cause of the increasing magnitude of disasters, since the colonisation changed the patterns of settlements (M.Pelling, 2003) without worrying why an area with good soil was so sparsely populated (A.Oliver-Smith, 1999). Moreover, global climate change is emphasising the trend. Projections are not particularly optimistic, since all increases in population in the so-called developing countries over the next years will occur within the city. This will further increase the unbalance on the ecosystem in the peripheral and weak areas surrounding the cities. They are extraordinarily exposed because, even though poorness and urban expansion do not by themselves imply intensification in the number of environmental disasters, they generate a lack of participation in seeking to improve general resilience. Population growth causes an increased need of apartments, services and infrastructures. Urban design process needs thus to be focused on prevention of disastrous events, particularly the water-related ones, as most of people live on a river, close to coasts or in the proximity of a river delta.

The River Thames is not used as the main infrastructure passing through the city anymore. Trade activities, port exchanges, fish-related enterprises, shipyard activities, and sport and leisure centres are not connected to the river with the same intensity of the recent past. Consequently, the structure of the city (the urban fabric) and the infrastructures have been adapting to the new condition. This gradual change determined a cir-

[12] Svensen H., 2009, *The End is Nigh. A History of Natural Disasters*, Reaktion Books Ltd, London, pp. 14,15

cular logic that has been weakening the use of the river. Embankments and other kind of levees are actually considered infrastructural interventions aimed at controlling water. Some forethoughts are thus necessary, as the term «infrastructure», always used for facilities connecting two elements or more, has actually assumed a separation meaning. The river—and water in general—has become the natural element against which we have to defend. New urban developments should try to strengthen the relationship with water, re-establishing both a physical contact and a social value. In this perspective, it could be possible to determine areas that can be flooded and other that need to be prevent from floods. Two fundamentally important documents for managing flood risk for Britain and the Thames areas have been set up: the PPS25 and the TE2100 Plan.

The *PPS25, Planning Policy Statement 25, Development and Flood Risk Practice Guide*[13], was published by the Department for Communities and Local Governments in 2009. In determining the relationship between National Planning Policies, Regional and Local Strategies, Flood Risk Assessment, and Planning Actions, the Flood Risk Management hierarchy is determined as follows (in process sequence):

- Assess: Undertake studies to collect data at the appropriate scale and level of detail to understand what the flood risk is;

- Prevention: Allocate developments to areas of least flood risk and apportion development types vulnerable to the impact of flooding to areas of least risk;

- Substitution: Substitute less vulnerable development types for those incompatible with the degree of flood risk;

- Control: Implement flood risk management measures to reduce the impact of new development on flood frequency and use appropriate design;

- Mitigation: Implement measures to mitigate residual risks.

An essential chapter of the PPS25 regards the use of the Sequential Test, a decision-making tool aimed to ensure that developments in areas at low risk of flood are preferable to sites at higher risk. In this perspective, four specific Flood Zones are determined, depending on the annual probability of river or sea flood (zone 1: $<0.1\%$; zone 2: $1\%>P>0.1\%$ for river flooding, $0.5\%>P>0.1\%$ for sea flooding; zone 3a: $P>1\%$ for river flooding, $P>0.5\%$ for sea flooding; zone 3b: $P\geq5\%$). A Flood Risk Vulnerability Classification (Fig. 1.11) is also identified, dividing man-made sites in essential infrastructures, highly vulnerable, more vulnerable, less vul-

[13] Department for Communities and Local Government, 2009, *Planning Policy Statement 25: Development and flood risk*, Crown Copyright, London.

Flood Risk Vulnerability classification (see Table D2)		Essential Infrastructure	Water compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone (see Table D.1)	Zone 1	✔	✔	✔	✔	✔
	Zone 2	✔	✔	Exception Test required	✔	✔
	Zone 3a	Exception Test required	✔	✗	Exception Test required	✔
	Zone 3b 'Functional Flood plain'	Exception Test required	✔	✗	✗	✗

Fig. 1.11
Flood risk vulnerability and flood zone 'compatibility'.
(Planning Policy Statement 25: Development and flood risk, Annex D)

nerable, and water-compatible development. Then, Flood Zones and Flood Risk Vulnerability classification are set into a table so that the appositeness of development within specific zone is given, and when the Exception Test must be conducted. This second test has lead to the validation from LPA, the Local Planning Authority[14].

The *TE2100 Plan, Thames Estuary 2100 Plan, Managing flood risk through London and the Thames estuary*, is an Environment Agency document setting out references for flood risk management for London and the Thames estuary today and in the future. The Thames floodplain has been subdivided into nine action zones, and deep analysis and recommendations are provided for each one of these[15].

Assessments, statements and policies are extremely well pointed both in the analysis and in the outcomes, but the quantity and the variety of these is overloading the datasets. In addition to that, information coming from other stakeholders, maps, forecasts, etc. has to be added in order to have an overall vision of the complex reality. City complexity often obstructs disaster resilient planning because of the multi-layered structure of communities. The variety and the quantity of layers forming the city (that shall be shown in the *Telematic Map of Risk*, Ch. 3.1.1.) have been proportionally growing depending on population growth, frequently bringing institutional and governmental Agencies to paralysis or even to collapse. Even though complexity was always born to solve problems, when it itself leads to slow community organisation, it is necessary to get rid of "toxic complexity[16]", in order to resolve inefficient issues (J.A.Tainter, 1988). Technological innovation, although imperative, can only solve short-term problems, as it quickly becomes obsolete. But if it is part of a flexible and adaptable system, it becomes the complementary tool necessary to connect the large and the small scales of the city.

[14] Department for Communities and Local Government, 2009, *Planning Policy Statement 25: Development and flood risk, Annexe D*, Crown Copyright, London.

[15] Environment Agency, 2012, *Thames Estuary 2100 Plan, Managing flood risk through London and the Thames estuary*, Environment Agency Copyright, London.

[16] Tainter J.A., 1988, *The Collapse of Complex Societies*, New York & Cambridge, UK.

Introdotte le componenti teoriche, la trattazione prosegue stabilendo gli strumenti di analisi necessari per la manipolazione di dati ambientali. La Sezione 2.1.1 esplicita la scelta di Londra come caso studio della ricerca. Segue, nella Sezione 2.1.2, l'analisi SWOT di quattro casi studio selezionati e lo studio del Tamigi lungo la storia, al fine di fornire modelli per le successive scelte a livello ambientale. La Sezione 2.2.1 introduce l'uso di big dataset come risorsa principale di informazione per la progettazione a scala urbana ed architettonica. Per completare le informazioni sull'uso dei dati, nella Sezione 2.2.2 è spiegato come nuove tecnologie e discipline entrano nel campo dell'architettura. Un excursus circa la nascita e l'evoluzione tecnologica delle mappe è discusso nella Sezione 2.3.1. Le mappe digitali aprono nuove frontiere per la relation fra spazio-tempo ed il processo di mappatura. Nella Sezione 2.3.2 i concetti fondamentali di analisi geospaziale vengono analizzati.

Having introduced the background topics, the research continues establishing the analytical tools needed for environmental data manipulation. Section 2.1.1 starts by explaining the choice of London as case study of this dissertation. It is followed, in Section 2.1.2, by the SWOT analyses of four selected cases, and the studies of the River Thames over history, in order to provide models for future environmental decisions. Section 2.2.1 introduces to the use of big dataset as the main source of information for design process on the urban and architectural scales. To complete data uses' information, in Section 2.2.2 the way new technologies and other sectors enter architectural field is explained. An excursus on maps, and innovative aspects in the telematic ones is discussed in Section 2.3.1. Digital maps open new territories regarding the relationship between space-time and mapping processes. In Section 2.3.2 basic concept of geospatial analysis are dealt with.

2 A SOCIETY TAILORED TO GLOBAL WARMING

Learning from the past

London. Catastrophes, technology, and networks 2.1.1

At this stage of the dissertation, the choice of London as case study of the research must be explained.

1. London is the city in which a number of catastrophes occur every year, but few people notice them, and understand their importance, risk, and social impacts. These mutations render the city dynamic. In London 'the end' has already happened many times, and the strength of this city is being able to change continuously and rapidly. These fascinating frenetic changes had often lead to the interweaving of so many issues that the complex became complicated, and London has made many mistakes in terms of urban planning and architectural design. The higher the number of unsolved complexities, the more fragile the city is. Water-related studies and engineering works have fostered vibrant debates that made the commonalty aware of London's issues. People's preparedness becomes in fact prevention in a city where all the dynamics and transformations run faster than the most of other realities. This speed facilitates new urban developments, which means that virtuous cases are helped in creating solid networks, but also that rough circumstances can take over with the same rapidity.

2. Its high standards of technological devices and platforms allow deep analyses in the fields this research is set. Indeed, big data availability guarantees sophisticated studies to be conducted, trying and find new correlations between phenomena and their manifestations. Both Agencies and University Departments have been working with big datasets, in order

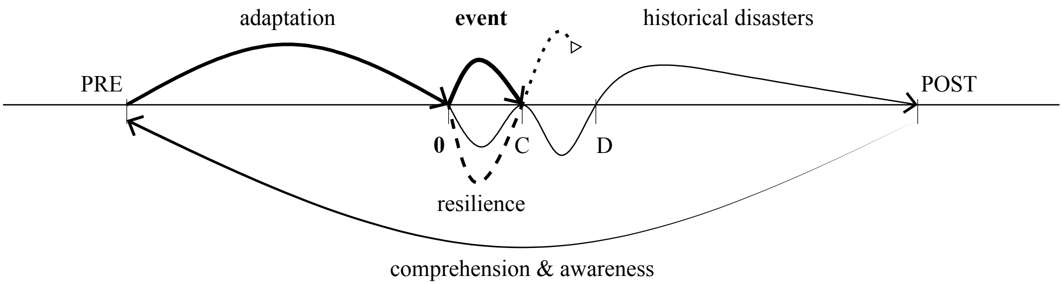


Fig. 2.1
Scheme of the ‘time machine’ to prevent catastrophic events to become disasters, by thea Author.

to evaluate current plans, and design strategic operative strategies for the city to come. The possibility to work with data, creating an overall risk analysis and a network of virtuous cases, is aimed to elevate the city to a diffuse system that works holistically towards a global water management.

3. The River Thames is characterised by two contrasting water stream directions between Kingston-Teddington and the Estuary. In fact, the river flow is from West to East, whereas the estuarine tide rises from East to West. This condition creates a complex dynamic to deal with, whose management is administered on the territorial, urban, and architectural scales alike. Thus, water system management is an issue not simply related to engineering and the Environment Agency, but regards also politics, through the development of sustainable environmental policies; architects, as urban developments must respond to a global system; anthropologists, because communities are tackling important societal changes; and many other sectors that can help to render water realities in the most complete way.

Thus, the aim of this research is to deal with the following issues:

- *water control* (allow water to enter the city)
- *urban flexibility* (infrastructures allowing structural dynamics)
- *social resilience* (let people conduct normal lives)

Societies over time 2.1.2

This chapter is aimed to demonstrate how to learn from past disastrous events, in order to prevent other communities to undergo similar phenomena. The vulnerability to any hazard can be lowered transforming the comprehension of past catastrophes and disasters into know-how for the future (Fig. 2.1).

Post disaster phase is both a recovery period and a defence setting against the possible catastrophic event to come, for communities that have undergone such an event. As one community is hit by a disaster, beside the desperation, a spontaneous movement of solidarity starts. People help each other in trying and find survivors, building temporary shelters, and finding funds for the first aids. It is a well known fact that, '[w]hen people are pushed to their very limits, it is often religion that is left at their only hope. Religion had an important therapeutic role after disasters.' And after having past the dismay and the fear, the recovery activities start, with the average schedules of such large events (Fig. 1.4).

At the same time, post-disasters are also observation cases for those communities that are coping with similar hazards. Some communities' experience of one disaster is an input for others to better understand their own level of resilience: the analysis of causes and aftermaths must lead Local Authorities to evaluate the state of local prevention measures. Projects need to capitalise on a combination of political, ecological, and economic factors to create a comprehensive flood strategy—resist, delay, store, discharge—that both defends the entire city, and enables commercial, civic, and recreational amenities to take shape.

Among the one hundred one considered[1], four case studies were explored in depth, due to their vary nature of causes, consequences, and resolutions. Moreover, they are representative for a specific issue related to water management. These are:

- Nile River, Egypt
- IJsselmeer, The Netherlands
- Arno River, Italy
- Mississippi River, U.S.A

To collect and analyse historic cases provides models for future environmental decisions. Specifically, **SWOT analysis**—that lead to vulnerability analysis—provides a highly detailed spectrum of motivations and obstacles the communities were involved in. It shows how environmental hazards influenced planning decision beyond aftermaths. Emergency and recovery phases involve some categories of actors/stakeholders that for propagandistic, humanitarian or economical reasons have a central role in the management of the period lasting from a disastrous event to another one or, in the best hypothesis, from a disastrous event to a catastrophic one. The fields in which these subjects are involved are (α) political resilience; (β) capital manipulation; (γ) outsiders' aids; (δ) human resilience. (α) After a disastrous event, Governments need to restore their legitimacy through a rhetorical process aimed at showing its resilience. This condition is unambiguously evident whether one Govern is given direct power in the aftermath. (β) Capital is a very dynamic component of the post-disaster period, both in the short and the long term. Moreover, they can

SWOT analysis *is a structured planning technique used to evaluate strengths, weaknesses, opportunities and threats involved in projects or business contexts.*

[1] The list by the author of the floods with more than 10 deaths of the last 10 years; then the main floods of the last 50 years for each year; finally the most crucial ones, is in 'Notes'.

increase through well-conducted investments, as new infrastructures are able to carry even more incomes. (γ) In crisis phases, resilience of communities depends on political and financial influences exerted from the outside. Volunteers, solidarity committees, donations and insurances have a central role in post-disaster coordination. (δ) Any disaster shatters the stability of each individual who seeks refuge within the community sentiment. This reaction brings visible efforts in rebuilding the stability of the status quo, and provides prolific distraction from the contingency. After having identified the four main principles the post-disaster condition is based on, a SWOT analysis for each one of the four case studies has been conducted (Figures 2.3, 2.4, 2.5, 2.6). Then, a global vulnerability analysis was drawn up, in order to identify the general criteria that shall shape the map of the risk, and thus new policies and planning decision.

Nile River, Egypt

The annual flood cycle of the Nile brought high water and natural nutrients along the whole floodplain, until the Aswan Dam was erected in 1960s. The river was used to flood down the valley during late summer, from the East Africa drainage basin. It flows from the mountains of Tanzania for 6,853 kilometres (4,258 miles)[2] northwards to the Mediterranean Sea. The importance of the river for Egyptian culture is strictly connected to the use of water both as an essential resource, since it is the major source in this desert area, and a trade infrastructure. Nowadays about 50 million people live within few miles of the river path.

The High Dam was built after the Old Aswan Dam became inadequate as a storage capacity for the planned developments. It has been protecting Egypt from flood and droughts in recent years, increasing agricultural production and employment. Great benefits have also been coming from electricity production—the 2.1 GW generators[3] allowed most Egyptian villages to have electricity for the first time—and navigation for trade activities.

Conversely, Aswan Dam flooded a vast area, leading to the displacement of over 100,000 people, and submerged many archaeological sites. Moreover, the dam is responsible for coastline erosion, and fishing decline, due to the loss of nutrients that are trapped behind it.

[2] Ministry of Irrigation & H. E. E. of the Democratic Republic of the Sudan, 2007, *Control and Use of Nile Waters in the Sudan*, Khartoum University Press, Khartoum.

[3] Abu-Zeid M.A., El-Shibini F. Z., 1997, *Egypt's High Aswan Dam*, University of Rhode Island, Kingston, USA.

IJsselmeer, The Netherlands

The Netherlands, Belgium, England and Scotland were struck by a coastal flood during the night between January 31st and February 1st, 1953. The peak high waters reached a height of 5.6 metres (18.4 ft).[4] The catastrophic event was caused by the combination of a high spring tide and heavy windstorms. The Netherlands was the country mostly affected, due to its landform. In fact, fifty per cent of its land is one metre below mean sea level, and twenty per cent of it is below mean sea level. Many levees in South Holland, North Brabant and Zeeland provinces were unable to resist to that combination of events, causing floods in the mainland, the polders, and the islands alike. Several adjacent countries, volunteer associations and benefactors provided aids, donations and directly helped with workforces.

Great attention was given to relief efforts and large-scale water management: dyke breaches were close for several months after the disaster, and political discussion about water resilience led to the completion of the *Zuiderzeewerken* (Zuiderzee Works) and the *Deltawerken* (Delta Works), through the establishment of the Delta Committee. The sea level rise, due to climate change, demands constant discorse about dike condition. For instance, the Oosterschelde and Westerschelde dikes reinforcement has already started. The Delta Commission reported in September 2008 the necessity of a new massive programme, in order to strengthen water defences over the country[5].

River Arno, Italy

After a long period of steady rain, on the night between November 3rd and 4th, 1966 Florence underwent the worst flood in the city's history since 1557. The Arno River began flooding from 2:30pm until 8:00pm[6] on the day after, causing an invaluable economic and cultural damage to the city. Tuscan Government and National Civil Protection had not been able to cope with the catastrophic event, and over time, adequate protection measures had not been taken.

Comprehending the incomparable wealth and importance of Florentine heritage, many benefactors and organizations contributed to the conservation and restoration works, providing both manpower and fund-

4 Grieve H., 1959, The GreatTide: *The Story of the 1953 Flood Disaster in Essex*, Essex County Council.

5 http://www.deltacommissie.com/en/advies.

6 Clarkson, C., 2003, *The Florence Flood of November 1966 & Its Aftermath*, http://www.ndl.go.jp/en/publication/ndl_newsletter/135/lecture1_135_353.pdf.

ing. Currently, Regional Officials in Tuscany are responsible for a massive project, aimed to protect the areas within the floodplain from future floods and to preserve high water quality. These works started in 1984, with the construction of the Bilancino Dam, and the spillway at Pontedera.

Florence recovered through its own efforts, with the contribution of volunteers, but without a decisive intervention from the Government. Numerous strengthening works of the banks that have been taking place over the years have the same inconsistency of similar attempts that followed the flood of 1844. Moreover, there are still doubts about the effectiveness of an emergency plan that has been prepared without informing the local people. After nearly half a century of urban development and demographic accumulation, the risk of a repeated disaster is the same.

Mississippi River, U.S.A

Known as “the Great Flood of 1993”, the disaster that affected the Mississippi and Missouri floodplains lasted for about seven months, and was characterised by several flooding over that period. It has been evaluated as the most tragic and costly water-related disaster that ever occurred in the United States. Violent rains and heavy snowfalls hit the Upper Mississippi River Basin during the autumn and winter 1992-1993. These were the prelude for the catastrophic events, which were mainly caused by persistent storms in late spring and summer time. The Illinois, Mississippi, and Missouri Rivers flowed together and it was evaluated that more than 80% of the levees (95% agricultural ones) along the Missouri River were overpassed or broken[7]. Instead, urban areas were not protected by levees or floodwalls destroyed, and the most densely populated areas remained protected.

The flood resilient system for the Mississippi and Missouri Rivers is composed of three components: urban levees, agricultural levees, and water control reservoirs. The federal control reservoir system kept about $2.1\text{x}10^{13}$ litres (17 million acre-ft) of floodwater. St. Louis was reached by this water only after the peak in August 1993, reducing the flood level of about 90cm (3ft).[8] Some preventive measures, such as to remove non-essential uses from floodplain, to improve flood control dams, to restore floodplain wetlands, etc., have been taken into consideration, to allow these areas to cope with future wider extremes of weather patterns.

7 U.S. Army Corps of Engineers, St. Louis District.

8 Larson L.W., 1996, *The Great USA Flood of 1993*, http://www.nwrfc.noaa.gov/floods/papers/oh_2/great.htm.

The four analyses have been condensed into an overall SWOT analysis able to highlight the main opportunities and threats—derived from both strengths and weaknesses—that is going to guide the *Telematic Map of Risk*, and future policies and actions. The SWOT analysis is formed on the correlation between strengths, weaknesses, opportunities and threats. That is, what kind of opportunities and threats can strengths lead to and what kind of opportunities and threats can weaknesses lead to. These factors are evaluated in the perspectives of (α), (β), (γ), (δ), as shown in the table of Figure 2.2.

This analysis brings to light how every urban intervention has a political meaning and a social impact on the community. Legislate towards a network of policies pivoted on the respect of the environment brings great benefits in terms of urban sustainability. On the other hand, it could simply remain a number of innovative ideas without any practical response if disjointed to programmes and plans, or if bureaucracy slows the design process. If so, the threat of urban sprawl can arise, creating a vicious circle with unfortunate capital management, or the one of total inactivity, and incapacity of reorganisation. Whether well connected to programmes and plans, good laws can drive investments, new jobs, and economic benefits for the whole community.

Another important consideration emerging from the case studies concerns first aids and interventions. As a number of volunteers, associations, and Agencies reach the unlucky territories very shortly to help local communities, a strong coordinated leadership must be form. This avoids excesses in autonomy from the individuals, and conflicting assignments and roles. Then, the population affected by the disaster is involved in the first aids too, and this responsibility helps it a lot in relieving the physical and mental pressure.

These prior topics based on political and human resilience, capital manipulation, and outsiders' aids are basic and absolute principles any decision-making activity must take into consideration for preventive actions and post disaster operations. Beside them, the knowledge of the source of the catastrophe is crucial. Indeed, having analysed other events from the past, comparing the SWOT analyses to a sort of time machine, one must translate all the issues to the contingency.

To know the cause of the hazard firstly means to understand the dynamic of the natural phenomenon (or phenomena), and the variations it can undertake due to anthropogenic alteration. For instance, the flow of a river can vary depending not just on its morphology and the atmospheric con-

swot analysis	S	W
O	political resilience: - debate and formation of laws - born of control boards and aid corporation capital manipulation: - investments in infrastructures & new cities - economic benefits from new infrastructures outsiders' aids: - volunteers involvement in saving people - formation of solidarity committees - national and international donations human resilience: - population involvement - take benefit from environm. opportunities	political resilience: - lack in the system leads to reorganisation - defence infrastructural and plans upgrading capital manipulation: - request of loans outsiders' aids: - volunteers provide equipment when lacking human resilience: - lack in defence lead to volunteers mobilitation
T	political resilience: - regulations without programmes and plans - bourocracy slowing design processes - uncontrolled urban expansion capital manipulation: - delays due to bureaucracy - flood insurances refer to direct payments and not to infrastructural improvements outsiders' aids: - absence of a coordinated leadership human resilience: - lack of land care - unauthorised buildings - top-down plans can cause disconnection within urban structure and society	political resilience: - Gov. inactivity in the aftermath management capital manipulation: - ubanisation causes reduction of soil absorption outsiders' aids: - excess of autonomy human resilience: - population not involved - defences under a safe level of protection

Fig. 2.2
Overall SWOT analysis, by the Author.

nile	S	W
O	political resilience: - capital manipulation: the annual economic benefit (agricolture, hydroelectric generation, flood resiliency, navigation) of the Aswan Dam after its completion (1970) was 255ml EGP against the 450ml EGP the works cost (cost recovery: 21 months) outsiders' aids: - human resilience: use of the river (mainly transportation); fertile land	political resilience: - capital manipulation: in 1954 Egypt asked loans to the World Bank (1bn $), withdrown in the end outsiders' aids: - human resilience: -
T	political resilience: - capital manipulation: - outsiders' aids: - human resilience: several disease were caused by insects	political resilience: - capital manipulation: - outsiders' aids: - human resilience: farmers have been forced to use about a million tons of artificial fertilizers to substitute the loam coming directly from the flood

MAIN DATA

date:	annualy until 1889, 1912, 1933
flow:	38 km^3/year (9.1 mi^3/year)
max level:	13.7 m (45 ft) at Aswan, 11.6 m (38 ft) at Luxor and Thebes, 7.6 m (25 ft) at Cairo
mud:	4,000,000 tons/year
deaths:	-
homeless:	-
main historic:	dam flood mitigation: 1964, 1973, 1988

Fig. 2.3
SWOT analysis for Nile River - Egypt.

Ijsselmeer	S	W
O	political resilience: the disaster(s) encouraged the debate that led to stregthening of dikes (89 dykes were collapsed), the *Zuiderzeewerken* and the *Deltawerken* (*Deltawet* 1958); the water control boards (*Waterschappen* or *Hoogheemraadschappen*) were founded in the 13th century	political resilience: flood defences are continuously be upgraded and strengthened as the sea level is rising and atmospheric phenomena are getting stronger; the lacks of the rescue operations management and scarse coordination between different Agencies led the EU to create the international programme ComCoast
	capital manipulation: important investments have been carried for infrastructures and the creation of new cities and towns; in 2009 the ComCoast countries partecipated to the flood rescue simulation FloodEx sponsored by the EU	capital manipulation: -
	outsiders' aids: national and international donations were collected; several countries sent soldiers and the US Army sent helicopters from Germany to rescue people	outsiders' aids: amateur radio operators provided their equipment for rescue operations
	human resilience: dykes and canals were military defences in themselves; population has actually been informed and involved in the mitigation and adaptation processes	human resilience: by controlled flooding in certain areas, military defences could be created; lack of radio informations and delay of the KNMI (Royal Netherlands Metereological Institute) led to a radio system reorganisation
T	political resilience: uncontrolled urban expansions	political resilience: -
	capital manipulation: -	capital manipulation: -
	outsiders' aids: -	outsiders' aids: -
	human resilience: top-down plans can cause disconnection within the urban structure that often leads to social issues	human resilience: -

MAIN DATA

date:	1953.01.31-1953.02.01
flow:	1,365 km^2
max level:	5.6 m (18.4 ft)
mud:	-
deaths:	1836 people
homeless:	72,000 people
main historic:	AD 838, 1014, 1163, 1170, 1212, 1219, 1280, 1362, 1675, 1703, 1820, 1825, 1836, 1916

Fig. 2.4
SWOT analysis for *Zuiderzeewerken* and the *Deltawerken* - The Netherlands.

arno	S	W
O	political resilience: regulations on land use (Lg.183/1989), basins regulation and land mapping	political resilience: 11 new basins, riverbed arrangement, new canals and the Bilancino Dam (1984-1993) designed under the supervision of the Consorzio Risorse Idriche
	capital manipulation: -	capital manipulation: -
	outsiders' aids: volunteers from Italy and abroad were involved in saving people and works of art; the CRAI (solidarity committee) was formed by many benefactors from Europe and the United States	outsiders' aids: -
	human resilience: massive aids from voluntaries lead to the formation of the Protezione Civile	human resilience: the absence of a civic defence lead to a great volunteers mobilitation for rescue actions and to the formation of the Protezione Civile
T	political resilience: regulations without programmes and plans; bourocracy slowing design processes, feasibility studies were not carried on	political resilience: the absence of a civic defence lead to a statal inactivity in the aftermath management which can even obstacle other agencies
	capital manipulation: delays due to bureaucracy	capital manipulation: countriside ubanisation concurr to the reduction of soil absorption
	outsiders' aids: absence of a coordinated leadership	outsiders' aids: -
	human resilience: lack of land care; unauthorised buildings	human resilience: population has not been informed and involved in the mitigation and adaptation processes

MAIN DATA

date:	1966.11.04
flow:	4,200 m^3/s
max level:	6.7 m (22 ft) around Santa Croce
mud:	600,000 tons
deaths:	30 people
homeless:	50,000 families
main historic:	AD 1177, 1269, 1333, 1557, 1740, 1844

Fig. 2.5
SWOT analysis for the River Arno - Italy.

mississippi	S	W
	political resilience: CAP (Civil Air Patrol), the congressionally volunteer corporation, assisted the victims and inspected the areas affected during the flood; the National Weather Authority is actually responsible for flood warnings capital manipulation: the Federal Government has spent 1bn $ to buy 25,000 flooded proprieties nationwide to turn the built areas into unurbanised lands outsiders' aids: - human resilience: -	political resilience: FEMA (Federal Emergency Management Agency) published risk assessments encouraging to move out of the flood plain; flood defences continuously need to be upgraded and strengthened (70% of levees were damaged) capital manipulation: - outsiders' aids: - human resilience: -
O T	political resilience: - capital manipulation: the flood insurance program refers to direct payments and not to infrastructural improvements outsiders' aids: - human resilience: -	political resilience: the Upper Mississippi River Flood Control System prevented just part of the damages occurred ; urbanisation of the flood plain reduced water infiltration rate; the channelisation of some part of the Mississippi made the flood impact worse capital manipulation: countriside ubanisation concurr to the reduction of soil absorption outsiders' aids: - human resilience: many levees—95% were agricoltural ones—were built under a safe level of protection, without federal knowledge; communities are not informed enough about the likelyhood of other devastating floodings; some people and communities decided to live together with the flood risk

MAIN DATA

date:	1993.04-10
flow:	av: 15,321 m^3/s (541,000 cfs); pk: 30,600
max level:	5.8 m (19 ft)
mud:	-
deaths:	52 people (along the whole flooded area)
homeless:	62,000 families (whole flooded area)
main historic:	AD 1844, 1851, 1903, 1927, 1951, 1973

Fig. 2.6
SWOT analysis for Mississippi River - U.S.A.

Fig. 2.7
London Bridge
Long View of London from Bankside (detail), Wenceslaus Hollar, 1647.

ditions, but also on cementification or canalisation works. Then, the history of the source is highly interesting as well, as its natural attitudes and features can emerge. To be aware of its history also means being able to understand the relationship between humans, and the built and the natural environment. How they dealt with hazards in the past can help decision-makers to embark on, or leave certain solutions. Back to London's analyses again, the next step is to study its source of floods.

A number of Londoners' lives have been in tight relations to the River Thames. It has always been a river for trade and commerce. Since the 3rd millennium B.C. with copper and tin, to the large industries and depots of the 1930s, many people owe a lot to the Thames. Thousands of ships and boats, vessels and barges were running across it everyday, shaping its path, and defining its boundaries. Many boats were also sailing the river for fishing activities. In the 15th century one could find barbels, pikes, tenches, eels, salmons, and sturgeon in the Thames[9]. Londoners earn a living through its exploitation, complementary activities, and its management. The Thames mostly flourished at the beginning of the 19th century. In fact, the turnover tripled from the 1700 to the 1800: 80 per cent of the entire national importations, and 70 per cent of the exportations were based on London docks.

«Thames» is an ancient name of uncertain origin. It is presumed to have the same etymology of the rivers Tamar, Teme and Taff. It could come from Celtic «tam», meaning 'smooth' or 'wide-spreading'. Its suffix comes from the Celtic root «isa», or «sea», which means 'running water'. But there are many other rivers with very close names: the river Temes, in Hungary; the river Tamese in Italy; and there is also a tributary of Gange, known in Sanskrit as «Tamasa», which means 'dark'.[10] So, some assume the name «dark river» could be pre-Celtic, and deriving from the primordial tribes of the Mesolithic or Neolithic periods. The Romans, at the age of Julius Caesar, translated the name into Thamesis, then transformed into «Tames» by Saxons. Finally it became «Thames».

The river is also a precious archaeological site. Since the first populations were settled on its banks, these consigned the Thames their deceased. The many skulls found at Chelsea suggest its riverbed could have been the oldest burial 'ground' of London. The dark side of the river is also connected to the number of drowning victims and suicides, and to

[9] Ackroyd P., 2000, *London: the biography*, Chatto & Windus, London.

[10] Ackroyd P., 2007, *Thames: sacred river*, Chatto & Windus, London.

some degraded and dangerous areas, such as it was Wapping, Shadwell, or Jacob's Island. Those had been lawless territories, principally due to the immoral work conditions at the docks, which drove entire communities to alienation, poverty, and alcoholism.

A strange dichotomy has been characterising the Thames over history: it has always been the river of dead and alive. The strong connection between people and water is also highlighted by documents about banquets, feasts, celebrations, and diplomatic events. Music, flags, arras, coat of arms, and pompous decorations on ships and boats crowned bombastic events. The area between London Bridge (Fig. 2.7) and the Tower of London, called the 'Pool of London', was full of boats almost to the limit, and they were mainly berthed next to flight of stairs that were connecting the river to the streets. Since the embankments were built (or strengthened whether already existing), this closeness ceased. As it happened in Rome at the *Porto di Ripetta* on the river Tiber, the banks and roads were radically shifted and reconstructed, in order to improve the flooding defences and capital city's transportation system.

At the end of the 18th century, a programme to speed up and control all the importation and exportation activities was launched, and in 1799 the West India Dock Company Act was approved. Then, Wapping's London Dock, Blackwell's East India Dock and Rotherhithe's Surrey Docks began (fig.2.8), and, beside the docks, many infrastructures were upgraded as well. The vast private effort is considered the utopia of trade made real, and indeed it had been of great benefit for the whole chain of commerce based on the Thames. This is recounted as follows:

Main trade goods:
- beer
- biscuits
- cocoa
- coffee
- cotton
- cress
- marbles & stones
- metals
- pepper
- porcelain
- ropes
- rum
- sugar
- sweet corn
- tea
- tobacco
- works of art

Fishing:
- barbels
- dublin bay prawn
- eels
- flounders
- lamprey
- pikes
- red mullet
- salmons
- sturgeon
- tenches

Complementary activities (infrastructural):
- dikes & levees construct. & management
- wharves & docks constr. & management
- locks maintenance
- accommodations for sailors and taverns
- tourist activities

British Empire *the largest empire in history that for over a century was the foremost global power. By 1922 the British Empire held sway over about 458 ml people, one-fifth of the world's population at the time.*

The growth of road transportation system, and the decline of the **British Empire** after 1914, reduced the commercial importance of the Thames. During the World War II, the protection of many facilities connected to the river, particularly water treatment sites and harbours, was essential to the water and energetic supply of the country. Even though the Port of London persist in being one of the UK's main ports, following the end of the war most trade was displaced downstream from central London.

Between the late 1960s and the very beginning of the 1980s all the docks have been dismissed, as the industrial process changed, the intermodal container appeared, and the dimension of the ships increased. Also the importance and use of the main canals and tributaries, such as Regent's Canal and the River Lee, changed drastically. In a decade the areas were radically transformed, locating new dwellings, hotels, and malls. Canary Wharf was transfigured in the financial district characterised by the cluster of gleaming skyscrapers where the worldwide most powerful companies are settled. Albeit questionable, the Isle of Dogs redevelopment is the proof of the adaptive capacity of the River Thames to fit any contemporary contingency. Again as for the industries and depots of nearly two hundred years before, the vast architectural project, as well as the infrastructural one, was built on private investments with the aid of tax incentives.

Beside the success of prolific areas and cities facing the Thames, there is another reality almost forgotten by any economic and political ethics. That is, wherever a piece of the floodplain is not particularly lucrative, this is set on the margins of political and environmental domains. In fact, there are not planned infra-structural interventions to preserve these areas from widespread impacts and damages brought by seasonal storms (mainly winter ones) causing river and groundwater floods. Moreover, as anticipated in chapter 1.3.2, the enforced tide flooding of the hinterland through the Thames Barrier is a common strategy to preserve the trade and financial hubs.

For instance, the Thames swells to record levels from mid-December 2013 to mid-February 2014, and thousands of properties had been submerged, or at high risk. Many parts of the Thames Valley were flooded, levels in at least 10 places were at an all-time high, and some stations in the south of England had recorded over five months worth of rainfall. 'Initially most of the weather impacts related to the strong winds. [... Then], as rainfall totals accumulated, the focus of concern shifted from strong winds to flooding, including large river catchments such as the Severn and Thames'. (Met Office, 2014) The Berkshire and Surrey suffered a lot the consequences of heavy rains, and the Medway was subjected to tidal

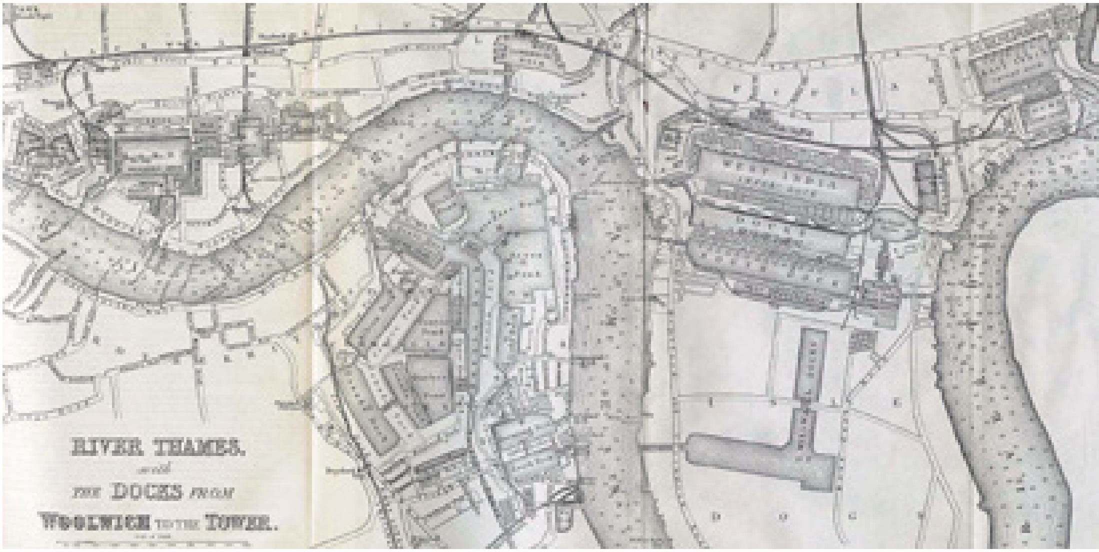
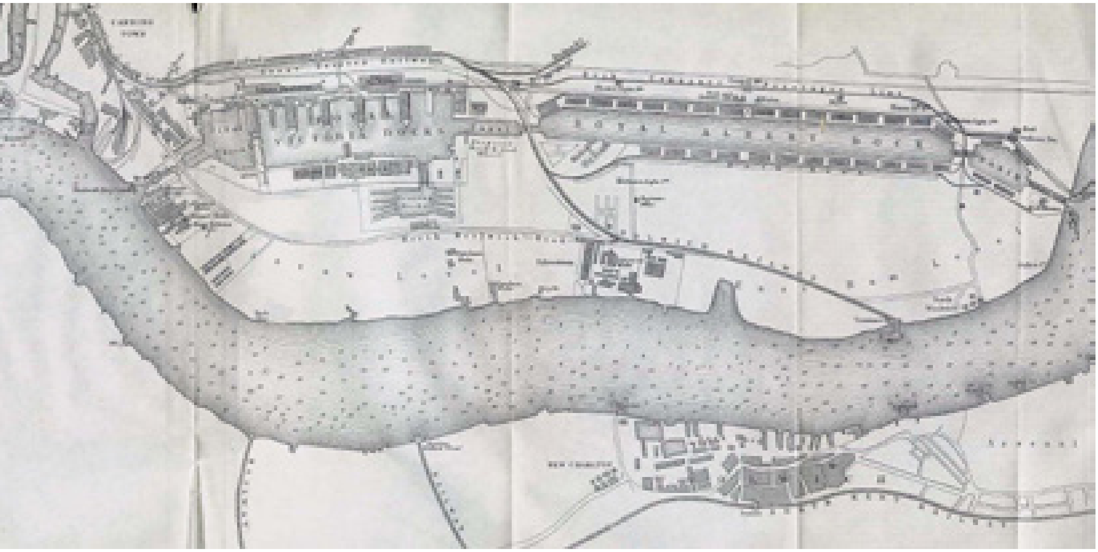


Fig. 2.8
River Thames with the Docks from Woolwich to the Tower [of London], 1882.
(A Dictionary Practical, Theoretical, and Historical of Commerce and Commercial Navigation)


ROYAL ALBERT DOCK

warnings; but the city of London was safe. What is going to happen in the near future, when the Thames Barrier will not be able to protect London anymore, will be the focus of the pilot case of this dissertation (see Chapters 3.2 and 3.3).

Other aftermaths must be highlighted as well. 'Agriculture is damaged by the destruction of cultivated land when a river breaks its banks, from flooding and changes to the groundwater level; shipping suffers from awkward shifts in the main channel and variations in water depths, and constructing hydroelectric plants is more expensive because their successful use is only possible on regulated watercourses.'[11] Moreover, strong winds and massive waves made conditions extremely dangerous around the south and west coastlines, and caused important transport disruption (Met Office, 2014).

But flooding, particularly in river floodplains, is as natural as rain and has been occurring for millions of years. The combination of low pressure and strong winds leads to significant storm surges (Met Office, 2013), and moon phases determine the tides. Famously fertile floodplains like the Mississippi Valley in the American Midwest, the Nile River valley in Egypt, and the Tigris-Euphrates in the Middle East have supported agriculture for millennia because seasonal flooding has left millions of tons of nutrient-rich silt deposits behind. The understanding of rivers dynamics is thus crucial, in order to re-establish that relation of trust and control of water taking over its natural needed space.

The cognisance of the nature of the river cannot be limited to the only area one is going to study, but it must be extended to the whole river. In fact, it would not be possible to understand the many correlations that interact, and determine specific states and phenomena (see Plate 2.1).

The entire UK is currently moving. Due to plate tectonics, the Southeast England is sinking slowly into water at the rate of approximately 305 mm (12 inches) per century. In 4000 B.C. the land beside the Thames was 14m (46ft) higher than it is now. Furthermore, the high tide has risen greatly over a period of two thousand years. The actual difference between tides is between 4.5 and 6.7 metres (15 and 22 ft)—depending on the season—at London Bridge, while in the Roman period it was little over 0.9 metres (3ft)[12].

The distinctiveness of the Thames—which is one of the main reason it was chosen as case study—is the two directions of water that character-

[11] Schaffernak, F., 1950, Grundriss der Flussmorphologie und des Flussbaues, Springer, Wien.

[12] Ackroyd P., 2007, *Thames: sacred river*, Chatto & Windus, London.

ise its stream. In fact the flow of the river is from West to East, from the Thames Head, in the Gloucestershire, to the Estuary, in Southend-on-Sea (Essex), where it meets the North Sea. On the other hand, the estuarine tide rise from East to West, as the North Sea is on the eastern side of the island. The Tideway, namely the part of the Thames that is subject to tides, is extended for about 160 kilometres (99 miles), from the Estuary to Teddington Lock, and includes the Thames Gateway and the Pool of London. Teddington Lock, in southwest London, controls the fall of water in order to preserve the navigability of the Thames even at low tide.

The River Thames is defended by over 180 miles of flood defence walls, embankments, and nine tidal barriers, including the Thames Barrier, as well as 35 major gates and over 400 minor gates which offer protection against a tidal flood event that has a 0.1% annual probability of occurring up to the year 2030. (Halcrow Group Ltd)

The main data of the River Thames are as follows:

length: 215 miles (346 km) - 191 miles (307 km) navigable
source: Thames Head, Gloucestershire (near Cirencester) - 110 m msl
counties: Gloucestershire, Wiltshire, Oxfordshire, Berkshire, Buckinghamshire, Surrey, Essex, Kent
average flow: Oxford: $17.6_{(i)}$ - $24.8_{(o)}$ m^3/s
Reading: 39.7 m^3/s
Windsor: 59.3 m^3/s
Teddington: 56.6 m^3/s
London: 65.8 m^3/s
decline: 17-21 inch/mile 27-34 cm/km), 600 ft (183 m) from head to sea
tide difference: ca 25 ft (7.6 m)

API, application programming interface *is a set of routines, protocols, and tools for building software applications. It defines functionalities that are independent of their respective implementations, which allows definitions and implementations to vary without compromising the interface.*

The Environment Agency flood-monitoring **API** provides developers with access to real time information covering: flood warnings and flood alerts, flood areas which to which warnings or alerts apply, forecast of flood risks over the next three days, measurements of water levels and flows, and information on the monitoring stations providing those measurements[13]. Real time measurements on a large number of stations allows to better understand causalities between a station and another, to calculate water level and flow rate variations over a period of time. Then, the association of these data to the weather information, and specifically the precipitation levels[14], completes the picture.

13 http://environment.data.gov.uk/flood-monitoring/doc/reference

14 http://www.weatheronline.co.uk/weather/maps

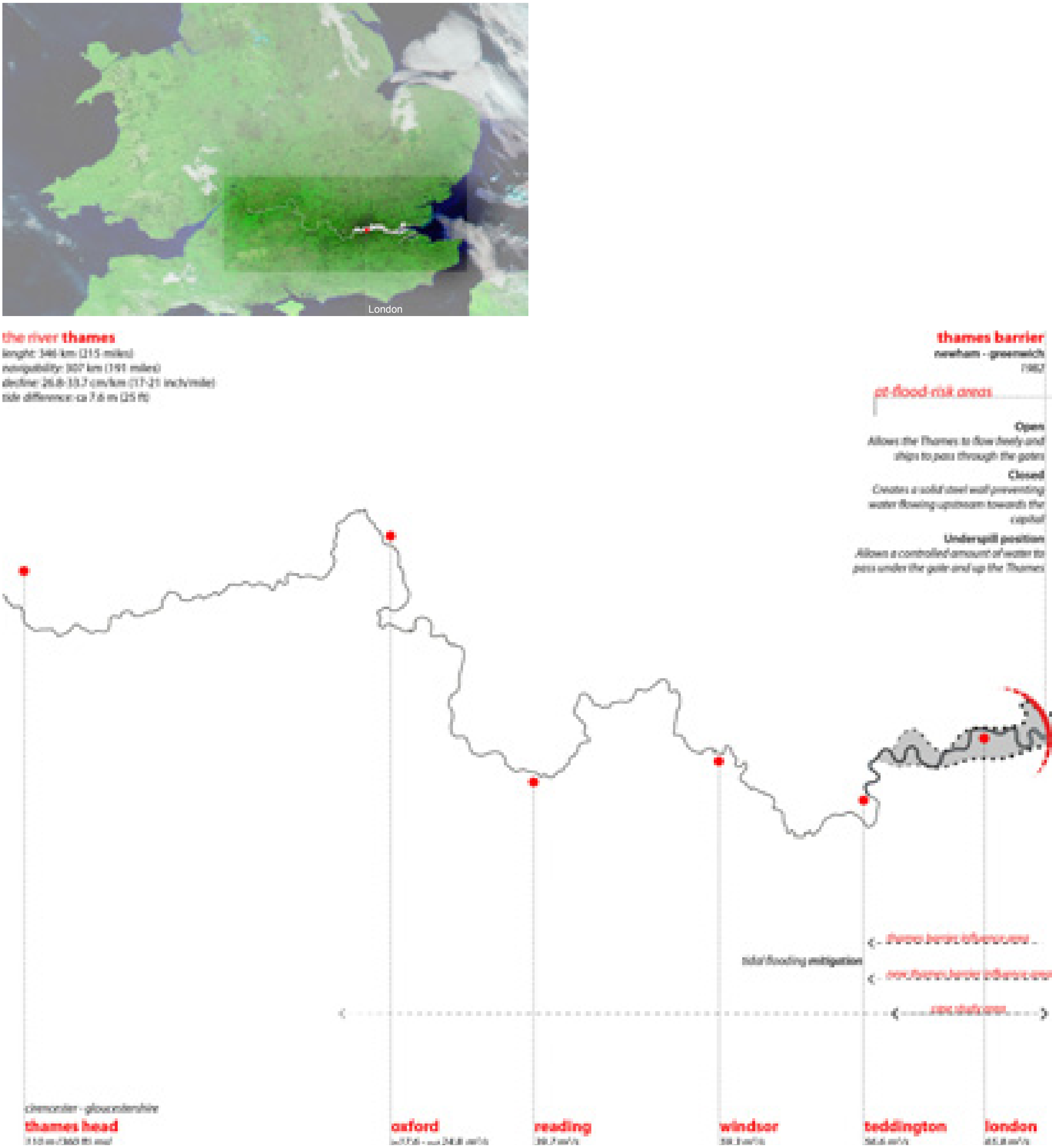
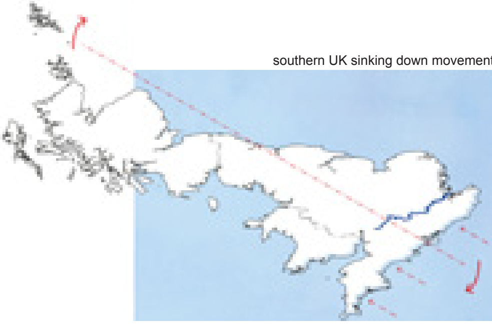
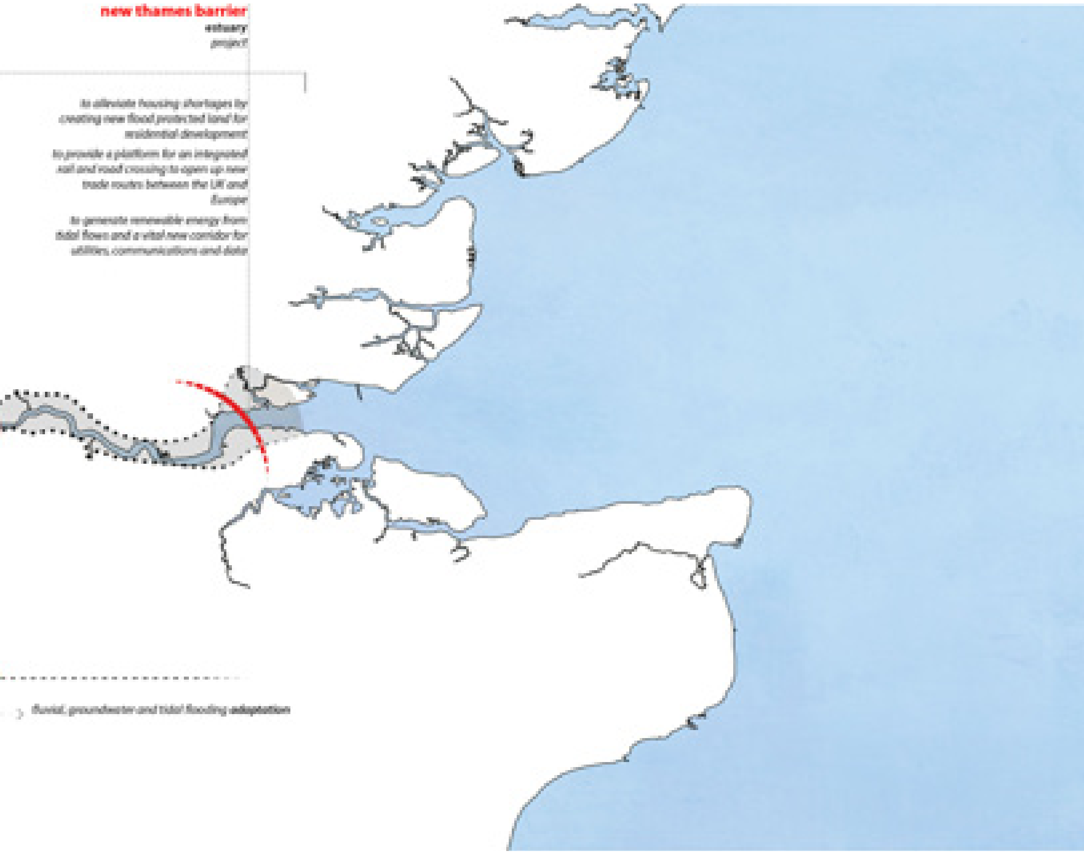


Plate 2.1
The River Thames from its source to its estuary, and water dynamics, by the author.

southern UK sinking down movement





Early data collection efforts have always been playing a key role in guiding decision-making. The larger and the more accurate the survey, the higher the quality of derived information. They provide qualitative features for the stream. Hydrometric data are gathered from stations around the United Kingdom using automatic field devices, usually every 15 minutes, and transferred via telemetry to internal and external systems real time. For this dissertation, the Thames is analysed at the stations of Kingston (Teddington), Richmond, and Silvertown. In so doing, three different areas are evaluated. Data form Kingston shows water dynamics upstream, where water flows West to East with little influences from the tide. Only in periods of very high fluvial flow the tidal influence can be seen as far upstream as East Molesey, location of the second lock on the Thames[15]. The second one, Richmond, provides data right after Teddington Lock, in West London. Then, Silvertown station is the closer one to the pilot case (see Ch. 3.1.1), where the River Lee meets the Thames.

The brief reports 2014-2015 for the critical months are shown in Figures 2.10 (a, b, c, d, e) and 2.11. The full reports can be found in Annex B, Section A.2. It clearly emerges how consistent flow and water level variations can be, and how important the control of the Lock is. As a proof of the tight relation between tides and weather conditions, a diagram of predicted and observed tide elevations at Lowestoft (Suffolk) on 5 to 6 December 2013 is reported (Fig. 2.12). It shows how weather conditions can affect tide predictions calculated on the lunar calendar; indeed, the surge was 2 m above predicted high water. All these indicators give back a wide spectrum of information about water features in specific points of the river, which must be used to master plan future developments. Moreover, in addition to the master planning, the cognisance of tide and flow states helps the design process as well. In fact, studies regarding new water paths, and shape improvement of buildings are only possible by the correct formulation of models based on real data (see Ch. 3.1.1).

15 http://www.spelthorne.gov.uk

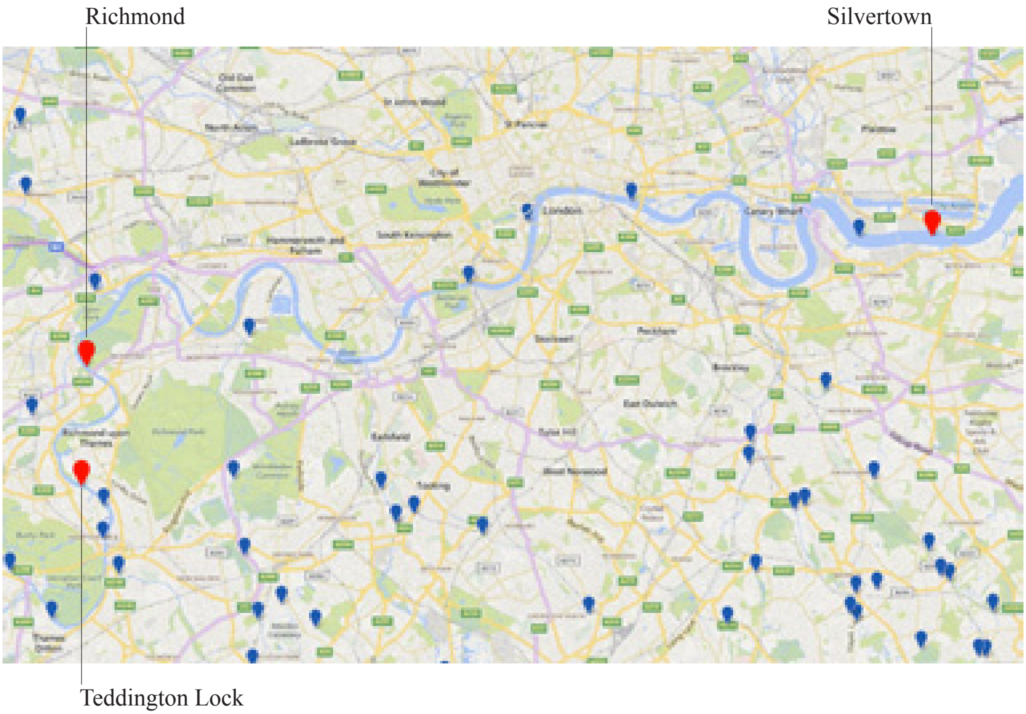


Fig. 2.9
The three stations of the Thames tideway analyses.

DATE			KINGSTON (Teddington)			RICHMOND		SILVERTOWN		LNDststd
OCTOBER	**level**	**flow**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**rain**
2014-10-07	max	**55.807**	-	**4.575**	-	**4.145**	-	**3.531**	-	3.0
fm	max	**46.342**	83%	**4.563**	100%	**4.537**	109%	**3.890**	110%	1.0
2014-10-09	max	**77.479**	167%	**4.725**	104%	**4.698**	104%	**4.231**	109%	3.0
2014-10-10	max	**92.841**	120%	**4.839**	102%	**4.808**	102%	**4.257**	101%	3.0
2014-10-11	max	**56.927**	61%	**4.631**	96%	**4.661**	97%	**4.099**	96%	0.5
2014-10-12	max	**51.924**	91%	**4.641**	100%	**4.624**	99%	**4.004**	98%	10.0
2014-10-13	max	**100.576**	194%	**4.688**	101%	**4.591**	99%	**3.876**	97%	17.0
2014-10-14	max	**105.786**	105%	**4.566**	97%	**4.207**	92%	**3.454**	89%	0.5
2014-10-15	max	**98.802**	93%	**4.589**	101%	**3.819**	91%	**3.165**	92%	9.0
2014-10-16	max	**84.758**	86%	**4.594**	100%	**3.591**	94%	**2.890**	91%	1.0
2014-10-17	max	**100.168**	118%	**4.607**	100%	**3.412**	95%	**2.729**	94%	1.0
2014-10-18	max	**86.995**	87%	**4.547**	99%	**3.364**	99%	**2.758**	101%	0.0
2014-10-19	max	**65.464**	75%	**4.487**	99%	**3.262**	97%	**2.923**	106%	2.0
2014-10-20	max	**50.684**	77%	**4.483**	100%	**3.613**	111%	**3.132**	107%	0.5
2014-10-21	max	**31.306**	62%	**4.509**	101%	**3.731**	103%	**3.861**	123%	3.0
2014-10-22	max	**66.424**	212%	**4.732**	105%	**4.720**	127%	**4.187**	108%	0.0
2014-10-23	max	**17.826**	27%	**4.488**	95%	**4.119**	87%	**3.575**	85%	0.0
nm	max	**30.014**	168%	**4.540**	101%	**4.485**	109%	**3.890**	109%	2.0
2014-10-25	max	**28.828**	96%	**4.535**	100%	**4.493**	100%	**3.960**	102%	0.0
2014-10-26	max	**19.350**	67%	**4.496**	99%	**4.280**	95%	**3.769**	95%	0.0
2014-10-27	max	**20.751**	107%	**4.506**	100%	**4.412**	103%	**3.821**	101%	0.0
2014-10-28	max	**18.607**	90%	**4.491**	100%	**4.229**	96%	**3.692**	97%	0.0
2014-10-29	max	**68.528**	368%	**4.519**	101%	**4.339**	103%	**3.744**	101%	3.0
2014-10-30	max	**19.873**	29%	**4.509**	100%	**3.833**	88%	**3.242**	87%	0.0
2014-10-31	max	**20.703**	104%	**4.503**	100%	**3.668**	96%	**3.132**	97%	0.5
2014-10-07	min	**18.376**	-	**4.420**	-	-0.306	-	**-2.996**	-	3.0
fm	min	**2.780**	15%	**4.410**	100%	-0.452	148%	**-3.033**	101%	1.0
2014-10-09	min	**9.327**	336%	**4.444**	101%	-0.401	89%	**-3.154**	104%	3.0
2014-10-10	min	**3.914**	42%	**4.431**	100%	-0.354	88%	**-2.879**	91%	3.0
2014-10-11	min	**11.858**	303%	**4.401**	99%	-0.636	180%	**-2.791**	97%	0.5
2014-10-12	min	**6.447**	54%	**4.412**	100%	-0.808	127%	**-2.564**	92%	10.0
2014-10-13	min	**19.204**	298%	**4.501**	102%	-0.167	21%	**-2.242**	87%	17.0
2014-10-14	min	**75.896**	395%	**4.464**	99%	0.544	-326%	**-2.157**	96%	0.5
2014-10-15	min	**28.278**	37%	**4.362**	98%	0.119	22%	**-1.850**	86%	9.0
2014-10-16	min	**54.572**	193%	**4.512**	103%	0.119	100%	**-1.634**	88%	1.0
2014-10-17	min	**67.667**	124%	**4.523**	100%	0.324	272%	**-1.417**	87%	1.0
2014-10-18	min	**52.747**	78%	**4.393**	97%	-0.086	-27%	**-1.751**	124%	0.0
2014-10-19	min	**43.213**	82%	**4.434**	101%	-0.064	74%	**-1.850**	106%	2.0
2014-10-20	min	**27.044**	63%	**4.411**	99%	-0.302	472%	**-2.018**	109%	0.5
2014-10-21	min	**8.033**	30%	**4.399**	100%	**-0.628**	208%	**-2.121**	105%	3.0
2014-10-22	min	**13.693**	170%	**4.452**	101%	**-0.658**	105%	**-2.546**	120%	0.0
2014-10-23	min	**6.923**	51%	**4.431**	100%	**-0.815**	124%	**-2.656**	104%	0.0
nm	min	**8.134**	117%	**4.452**	100%	**-0.735**	90%	**-2.487**	94%	2.0
2014-10-25	min	**1.433**	18%	**4.477**	101%	**-0.808**	110%	**-2.732**	110%	0.0
2014-10-26	min	**12.249**	855%	**4.471**	100%	**-0.786**	97%	**-2.549**	93%	0.0
2014-10-27	min	**8.518**	70%	**4.467**	100%	**-0.709**	90%	**-2.549**	100%	0.0
2014-10-28	min	**12.493**	147%	**4.471**	100%	**-0.844**	119%	**-2.505**	98%	0.0
2014-10-29	min	**9.860**	79%	**4.474**	100%	**-0.877**	104%	**-2.091**	83%	3.0
2014-10-30	min	**11.419**	116%	**4.472**	100%	**-0.757**	86%	**-2.289**	109%	0.0
2014-10-31	min	**14.226**	125%	**4.488**	100%	**-0.738**	97%	**-2.062**	90%	0.5

Fig. 2.10a
October survey, by the author.

			KINGSTON (Teddington)			RICHMOND		SILVERTOWN		LNDststd
NOVEMBER	**level**	**flow**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**rain**
2014-11-01	max	**19.163**	93%	**4.495**	100%	**3.580**	98%	**3.114**	99%	0.5
2014-11-02	max	**23.366**	122%	**4.520**	101%	**3.701**	103%	**3.264**	105%	12.0
2014-11-03	max	**73.663**	315%	**4.601**	102%	**4.240**	115%	**3.722**	114%	9.0
2014-11-04	max	**62.789**	85%	**4.548**	99%	**4.309**	102%	**3.960**	106%	17.0
2014-11-05	max	**81.188**	129%	**4.676**	103%	**4.610**	107%	**3.769**	95%	0.0
fm	max	**60.556**	75%	**4.561**	98%	**4.493**	97%	**3.901**	104%	1.0
2014-11-07	max	**40.708**	67%	**4.546**	100%	**4.123**	92%	**3.641**	93%	9.0
2014-11-08	max	**100.103**	246%	**4.736**	104%	**4.694**	114%	**4.110**	113%	4.0
2014-11-09	max	**131.433**	131%	**4.772**	101%	**4.668**	99%	**4.037**	98%	0.0
2014-11-10	max	**113.729**	87%	**4.745**	99%	**4.679**	100%	**4.004**	99%	0.0
2014-11-11	max	**63.679**	56%	**4.560**	96%	**4.401**	94%	**3.777**	94%	1.0
2014-11-12	max	**64.550**	101%	**4.561**	100%	**4.156**	94%	**3.539**	94%	4.0
2014-11-13	max	**91.629**	142%	**4.613**	101%	**3.819**	92%	**3.176**	90%	0.5
2014-11-14	max	**115.589**	126%	**4.576**	99%	**3.526**	92%	**2.854**	90%	12.0
2014-11-15	max	**135.239**	117%	**4.603**	101%	**3.775**	107%	**3.040**	107%	2.0
2014-11-16	max	**131.978**	98%	**4.554**	99%	**3.562**	94%	**2.912**	96%	1.0
2014-11-17	max	**118.734**	90%	**4.587**	101%	**3.767**	106%	**3.073**	106%	7.0
2014-11-18	max	**148.806**	125%	**4.613**	101%	**3.848**	102%	**3.224**	105%	0.5
2014-11-19	max	**129.740**	87%	**4.538**	98%	**3.906**	102%	**3.333**	103%	0.0
2014-11-20	max	**114.106**	88%	**4.562**	101%	**4.060**	104%	**3.399**	102%	0.0
2014-11-21	max	**91.970**	81%	**4.550**	100%	**4.251**	105%	**3.553**	105%	1.0
nm	max	**70.452**	77%	**4.503**	99%	**4.027**	95%	**3.421**	96%	2.0
2014-11-23	max	**113.288**	161%	**4.603**	102%	**4.687**	116%	**3.909**	114%	27.0
2014-11-24	max	**186.254**	164%	**4.890**	106%	**4.720**	101%	**3.938**	101%	0.5
2014-11-25	max	**217.765**	117%	**4.908**	100%	**4.804**	102%	**4.092**	104%	6.0
2014-11-26	max	**186.044**	85%	**4.826**	98%	**4.621**	96%	**3.861**	94%	6.0
2014-11-27	max	**197.769**	106%	**4.791**	99%	**4.537**	98%	**3.722**	96%	6.0
2014-11-28	max	**179.429**	91%	**4.634**	97%	**4.295**	95%	**3.528**	95%	0.5
2014-11-29	max	**158.352**	88%	**4.631**	100%	**4.005**	93%	**3.271**	93%	0.0
2014-11-30	max	**119.335**	75%	**4.464**	96%	**4.002**	100%	**3.308**	101%	0.5
2014-11-01	min	**11.276**	79%	**4.476**	100%	**-0.640**	87%	**-1.941**	94%	0.5
2014-11-02	min	**11.108**	99%	**4.475**	100%	**-0.570**	89%	**-2.168**	112%	12.0
2014-11-03	min	**21.026**	189%	**4.499**	101%	**-0.340**	60%	**-2.165**	100%	9.0
2014-11-04	min	**39.268**	187%	**4.426**	98%	**0.100**	-29%	**-2.264**	105%	17.0
2014-11-05	min	**24.697**	63%	**4.457**	101%	**0.090**	90%	**-2.436**	108%	0.0
fm	min	**15.532**	63%	**4.417**	99%	**-0.240**	-267%	**-2.820**	116%	1.0
2014-11-07	min	**13.811**	89%	**4.433**	100%	**-0.170**	71%	**-3.143**	111%	9.0
2014-11-08	min	**34.681**	251%	**4.492**	101%	**-0.170**	100%	**-2.645**	84%	4.0
2014-11-09	min	**21.908**	63%	**4.443**	99%	**0.270**	-159%	**-2.648**	100%	0.0
2014-11-10	min	**26.966**	123%	**4.408**	99%	**0.340**	126%	**-2.450**	93%	0.0
2014-11-11	min	**29.898**	111%	**4.408**	100%	**0.050**	15%	**-2.205**	90%	1.0
2014-11-12	min	**32.858**	110%	**4.462**	101%	**-0.050**	-100%	**-2.205**	100%	4.0
2014-11-13	min	**56.346**	171%	**4.514**	101%	**0.150**	-300%	**-1.886**	86%	0.5
2014-11-14	min	**71.650**	127%	**4.450**	99%	**0.490**	327%	**-1.663**	88%	12.0
2014-11-15	min	**108.580**	152%	**4.548**	102%	**0.850**	173%	**-1.524**	92%	2.0
2014-11-16	min	**91.332**	84%	**4.552**	100%	**0.610**	72%	**-1.502**	99%	1.0
2014-11-17	min	**95.678**	105%	**4.485**	99%	**0.720**	118%	**-1.626**	108%	7.0
2014-11-18	min	**115.253**	120%	**4.474**	100%	**0.830**	115%	**-1.919**	118%	0.5
2014-11-19	min	**92.646**	80%	**4.394**	98%	**0.720**	87%	**-2.077**	108%	0.0
2014-11-20	min	**74.715**	81%	**4.436**	101%	**0.530**	74%	**-2.308**	111%	0.0
2014-11-21	min	**49.978**	67%	**4.411**	99%	**0.490**	92%	**-2.348**	102%	1.0
nm	min	**47.403**	95%	**4.440**	101%	**0.110**	22%	**-2.667**	114%	2.0
2014-11-23	min	**57.829**	122%	**4.506**	101%	**0.410**	373%	**-2.399**	90%	27.0
2014-11-24	min	**111.855**	193%	**4.545**	101%	**1.225**	299%	**-2.461**	103%	0.5
2014-11-25	min	**154.489**	138%	**4.446**	98%	**1.350**	110%	**-2.520**	102%	6.0
2014-11-26	min	**119.925**	78%	**4.460**	100%	**1.225**	91%	**-2.465**	98%	6.0
2014-11-27	min	**152.423**	127%	**4.537**	102%	**1.364**	111%	**-2.447**	99%	6.0
2014-11-28	min	**146.101**	96%	**4.468**	98%	**1.126**	83%	**-2.267**	93%	0.5
2014-11-29	min	**129.066**	88%	**4.514**	101%	**0.888**	79%	**-2.242**	99%	0.0
2014-11-30	min	**112.541**	87%	**4.431**	98%	**0.591**	67%	**-2.154**	96%	0.5

Fig. 2.10b
November survey, by the author.

				KINGSTON (Teddington)		RICHMOND		SILVERTOWN		LNDststd
DECEMBER	level	flow	↑↓	water level	↑↓	water level	↑↓	water level	↑↓	rain
2014-12-01	max	94.902	80%	4.589	103%	3.903	98%	3.209	97%	0.0
2014-12-02	max	92.964	98%	4.580	100%	4.053	104%	4.053	126%	1.0
2014-12-03	max	74.854	79%	4.511	98%	3.756	96%	3.594	112%	0.5
2014-12-04	max	72.760	78%	4.497	98%	4.243	105%	3.344	83%	4.0
2014-12-05	max	70.544	94%	4.524	100%	4.258	113%	3.583	100%	0.0
fm	max	63.583	87%	4.546	101%	4.386	103%	3.744	104%	0.5
2014-12-07	max	54.958	78%	4.528	100%	4.115	97%	3.509	94%	1.0
2014-12-08	max	61.480	97%	4.556	100%	4.298	98%	3.674	105%	0.0
2014-12-09	max	57.016	104%	4.567	101%	4.482	109%	3.843	105%	1.0
2014-12-10	max	48.593	79%	4.529	99%	4.159	97%	3.568	93%	1.0
2014-12-11	max	51.293	90%	4.542	99%	4.137	92%	3.557	100%	0.5
2014-12-12	max	79.560	164%	4.544	100%	4.207	101%	3.535	99%	10.0
2014-12-13	max	126.196	246%	4.593	101%	3.947	95%	3.315	94%	0.0
2014-12-14	max	109.991	138%	4.511	99%	3.251	77%	2.681	81%	1.0
2014-12-15	max	78.523	71%	4.504	100%	3.668	113%	3.044	114%	0.5
2014-12-16	max	76.428	97%	4.498	100%	3.284	90%	2.799	92%	3.0
2014-12-17	max	114.595	150%	4.586	102%	3.815	116%	3.147	112%	5.0
2014-12-18	max	135.399	118%	4.554	99%	3.588	94%	2.982	95%	0.0
2014-12-19	max	130.628	96%	4.558	100%	4.225	118%	3.509	118%	1.0
2014-12-20	max	108.301	83%	4.486	98%	3.917	93%	3.462	99%	0.0
2014-12-21	max	99.386	92%	4.488	100%	4.159	106%	3.583	103%	0.0
nm	max	84.983	86%	4.548	101%	4.379	105%	3.718	104%	0.0
2014-12-23	max	71.099	84%	4.507	99%	4.364	100%	3.736	100%	0.0
2014-12-24	max	71.294	100%	4.488	100%	3.998	92%	3.696	99%	0.5
2014-12-25	max	n	-	n	-	n	-	n	-	0.0
2014-12-26	max	n	-	n	-	n	-	n	-	8.0
2014-12-27	max	n	-	n	-	n	-	n	-	1.0
2014-12-28	max	n	-	n	-	n	-	n	-	0.0
2014-12-29	max	n	-	n	-	n	-	n	-	0.5
2014-12-30	max	n	-	n	-	n	-	n	-	0.5
2014-12-31	max	n	-	n	-	n	-	n	-	0.5
2014-12-01	min	64.972	58%	4.377	99%	0.430	73%	-2.088	97%	0.0
2014-12-02	min	67.288	104%	4.476	102%	0.222	52%	0.222	-11%	1.0
2014-12-03	min	60.343	93%	4.444	102%	0.251	58%	-2.267	-1021%	0.5
2014-12-04	min	58.636	87%	4.455	100%	0.222	100%	-2.436	107%	4.0
2014-12-05	min	39.288	65%	4.377	98%	0.134	53%	-2.436	100%	0.0
fm	min	46.853	80%	4.461	100%	0.009	4%	-2.710	111%	0.5
2014-12-07	min	48.536	124%	4.490	103%	-0.108	-81%	-2.787	103%	1.0
2014-12-08	min	41.846	89%	4.449	100%	0.005	56%	-2.469	89%	0.0
2014-12-09	min	23.888	49%	4.400	98%	-0.130	120%	-3.143	127%	1.0
2014-12-10	min	28.169	67%	4.446	100%	-0.189	-3780%	-2.275	72%	1.0
2014-12-11	min	36.308	152%	4.468	102%	-0.189	145%	-2.425	107%	0.5
2014-12-12	min	42.288	150%	4.448	100%	-0.105	56%	-2.157	89%	10.0
2014-12-13	min	80.137	221%	4.469	100%	0.482	-255%	-2.018	94%	0.0
2014-12-14	min	61.171	145%	4.386	99%	0.357	-340%	-2.227	110%	1.0
2014-12-15	min	67.387	84%	4.498	103%	0.269	75%	-1.809	81%	0.5
2014-12-16	min	45.816	75%	4.430	98%	0.009	3%	-1.685	93%	3.0
2014-12-17	min	60.091	89%	4.429	100%	0.243	2700%	-1.828	108%	5.0
2014-12-18	min	90.356	197%	4.433	100%	0.661	272%	-2.106	115%	0.0
2014-12-19	min	107.037	178%	4.402	99%	0.819	124%	-1.938	92%	1.0
2014-12-20	min	92.450	102%	4.385	100%	0.657	80%	-2.139	110%	0.0
2014-12-21	min	66.483	62%	4.402	100%	0.401	61%	-2.960	138%	0.0
nm	min	79.831	86%	4.519	103%	0.243	61%	-2.615	88%	0.0
2014-12-23	min	50.302	76%	4.441	98%	0.130	53%	-2.703	103%	0.0
2014-12-24	min	69.692	87%	4.467	101%	0.280	215%	i	-	0.5
2014-12-25	min	n	-	n	-	n	-	n	-	0.0
2014-12-26	min	n	-	n	-	n	-	n	-	8.0
2014-12-27	min	n	-	n	-	n	-	n	-	1.0
2014-12-28	min	n	-	n	-	n	-	n	-	0.0
2014-12-29	min	n	-	n	-	n	-	n	-	0.5
2014-12-30	min	n	-	n	-	n	-	n	-	0.5
2014-12-31	min	n	-	n	-	n	-	n	-	0.5

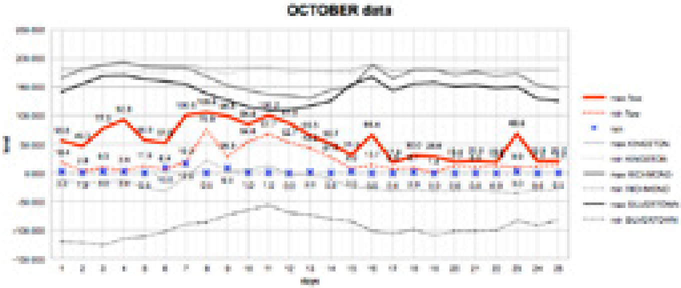
Fig. 2.10c
December survey, by the author.

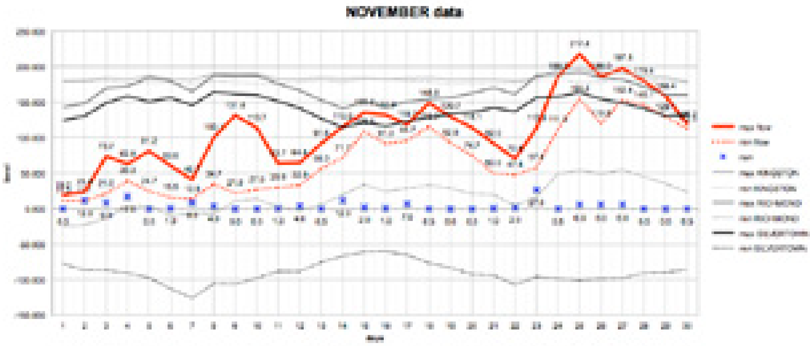
			KINGSTON (Teddington)			RICHMOND		SILVERTOWN		LNDststd
JANUARY	**level**	**flow**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**rain**
2014-01-13	max	**234.003**	-	**6.099**	-	**3.815**	-	**3.297**	-	0.0
2014-01-14	max	**205.858**	88%	**4.645**	76%	**3.899**	102%	**3.081**	93%	0.0
2014-01-15	max	**229.565**	112%	**4.660**	100%	**3.093**	79%	**2.260**	73%	6.0
2014-01-16	max	**266.933**	116%	**4.795**	103%	**3.954**	128%	**3.158**	140%	0.5
2014-01-17	max	**266.228**	100%	**4.750**	99%	**3.786**	96%	**3.154**	100%	0.5
2014-01-18	max	**200.258**	75%	**4.684**	99%	**4.163**	110%	**3.447**	109%	1.0
2014-01-19	max	**192.248**	96%	**4.688**	100%	**4.251**	102%	**3.495**	101%	0.5
2014-01-20	max	**171.267**	89%	**4.803**	102%	**4.577**	108%	**3.835**	110%	0.5
nm	max	**161.784**	94%	**4.814**	100%	**4.676**	102%	**3.978**	104%	1.0
2014-01-22	max	**153.309**	95%	**4.839**	101%	**4.705**	101%	**4.055**	102%	0.0
2014-01-23	max	**144.130**	94%	**4.803**	99%	**4.602**	98%	**3.905**	96%	1.0
2014-01-24	max	**154.515**	107%	**4.985**	104%	**4.760**	103%	**4.161**	107%	2.0
2014-01-25	max	**119.366**	77%	**4.640**	93%	**4.419**	93%	**3.780**	91%	0.5
2014-01-26	max	**119.998**	101%	**4.625**	100%	**4.342**	98%	**3.663**	97%	0.5
2014-01-27	max	**107.087**	89%	**4.515**	98%	**3.885**	89%	**3.359**	92%	0.0
2014-01-28	max	**112.455**	105%	**4.550**	101%	**3.936**	101%	**3.271**	97%	1.0
2014-01-29	max	**103.014**	92%	**4.559**	100%	**3.591**	91%	**2.960**	90%	1.0
2014-01-30	max	**96.684**	94%	**4.530**	99%	**3.767**	105%	**3.136**	106%	0.5
2014-01-31	max	**100.201**	104%	**4.529**	100%	**3.683**	98%	**3.044**	97%	3.0
2014-01-13	min	**65.052**	-	**2.919**	-	**0.844**	-	**-1.714**	-	0.0
2014-01-14	min	**166.849**	256%	**4.460**	153%	**1.273**	151%	**-1.802**	105%	0.0
2014-01-15	min	**189.300**	113%	**4.506**	101%	**1.412**	111%	**-1.949**	108%	6.0
2014-01-16	min	**218.605**	115%	**4.616**	102%	**1.654**	117%	**-1.780**	91%	0.5
2014-01-17	min	**178.849**	82%	**4.445**	96%	**1.390**	84%	**-2.223**	125%	0.5
2014-01-18	min	**164.792**	92%	**4.499**	101%	**1.328**	96%	**-2.088**	94%	1.0
2014-01-19	min	**147.050**	89%	**4.468**	99%	**1.236**	93%	**-2.458**	118%	0.5
2014-01-20	min	**89.593**	61%	**4.374**	98%	**1.020**	83%	**-2.546**	104%	0.5
nm	min	**88.753**	99%	**4.407**	101%	**0.830**	81%	**-2.586**	102%	1.0
2014-01-22	min	**74.258**	84%	**4.445**	101%	**0.800**	96%	**-2.850**	110%	0.0
2014-01-23	min	**62.439**	84%	**4.422**	99%	**0.533**	67%	**-3.062**	107%	1.0
2014-01-24	min	**2.266**	4%	**4.359**	99%	**0.734**	138%	**-2.710**	89%	2.0
2014-01-25	min	**75.167**	3317%	**4.379**	100%	**0.606**	83%	**-2.886**	106%	0.5
2014-01-26	min	**72.748**	97%	**4.390**	100%	**0.606**	100%	**-2.670**	93%	0.5
2014-01-27	min	**81.625**	112%	**4.365**	99%	**0.445**	73%	**-2.494**	93%	0.0
2014-01-28	min	**79.181**	97%	**4.351**	100%	**0.445**	100%	**-2.699**	108%	1.0
2014-01-29	min	**78.550**	99%	**4.441**	102%	**0.438**	98%	**-1.824**	68%	1.0
2014-01-30	min	**89.323**	114%	**4.448**	100%	**0.518**	118%	**-1.641**	90%	0.5
2014-01-31	min	**87.208**	98%	**4.396**	99%	**0.427**	82%	**-1.875**	114%	3.0

Fig. 2.10d
January survey, by the author.

		KINGSTON (Teddington)				RICHMOND		SILVERTOWN		LNDststd
FEBRUARY	**level**	**flow**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**rain**
2014-02-01	max	**88.453**	88%	**4.480**	99%	**3.591**	98%	**2.927**	96%	0.5
2014-02-02	max	**88.158**	100%	**4.566**	102%	**4.013**	112%	**3.374**	115%	0.0
fm	max	**89.688**	102%	**4.575**	100%	**4.280**	107%	**3.583**	106%	0.0
2014-02-04	max	**89.860**	100%	**4.537**	99%	**4.152**	97%	**3.469**	97%	0.0
2014-02-05	max	**78.056**	87%	**4.540**	100%	**4.254**	102%	**3.575**	103%	0.5
2014-02-06	max	**77.651**	99%	**4.531**	100%	**4.225**	99%	**3.524**	99%	0.0
2014-02-07	max	**73.791**	95%	**4.498**	99%	**4.002**	95%	**3.330**	94%	0.5
2014-02-08	max	**71.190**	96%	**4.493**	100%	**4.024**	101%	**3.396**	102%	0.0
2014-02-09	max	**69.781**	98%	**4.471**	100%	**3.972**	99%	**3.337**	98%	0.0
2014-02-10	max	**68.559**	98%	**4.460**	100%	**3.764**	95%	**3.132**	94%	0.0
2014-02-11	max	**64.082**	93%	**4.460**	100%	**3.522**	94%	**2.887**	92%	0.0
2014-02-12	max	**66.506**	104%	**4.488**	101%	**3.386**	96%	**2.857**	99%	0.0
2014-02-13	max	**73.720**	111%	**4.515**	101%	**3.115**	92%	**2.520**	88%	7.0
2014-02-14	max	**n**	-	**n**	-	**n**	-	**n**	-	0.5
2014-02-15	max	**n**	-	**n**	-	**n**	-	**n**	-	0.0
2014-02-16	max	**n**	-	**n**	-	**n**	-	**n**	-	6.0
2014-02-17	max	**n**	-	**n**	-	**n**	-	**n**	-	0.0
nm	max	**127.164**	-	**4.565**	-	**4.013**	-	**3.264**	-	0.0
2014-02-19	max	**125.601**	99%	**4.627**	101%	**4.328**	108%	**3.652**	112%	5.0
2014-02-20	max	**182.365**	145%	**5.171**	112%	**4.936**	114%	**4.429**	121%	1.0
2014-02-21	max	**188.933**	104%	**5.170**	100%	**4.932**	100%	**4.377**	99%	1.0
2014-02-22	max	**175.578**	93%	**5.084**	98%	**4.866**	99%	**4.231**	97%	7.0
2014-02-23	max	**181.307**	103%	**4.981**	98%	**4.734**	97%	**4.044**	96%	1.0
2014-02-24	max	**189.406**	104%	**4.873**	98%	**4.591**	97%	**3.813**	94%	0.0
2014-02-25	max	**164.814**	87%	**4.726**	97%	**4.324**	94%	**3.638**	95%	2.0
2014-02-26	max	**152.178**	92%	**4.519**	96%	**3.734**	86%	**2.975**	82%	5.0
2014-02-27	max	**149.250**	98%	**4.576**	101%	**3.478**	93%	**2.931**	99%	0.0
2014-02-28	max	**128.255**	86%	**4.563**	100%	**3.265**	94%	**2.597**	89%	2.0
2014-02-01	min	**80.791**	93%	**4.389**	100%	**0.427**	100%	**-2.018**	108%	0.5
2014-02-02	min	**61.558**	76%	**4.378**	100%	**0.364**	85%	**-2.267**	112%	0.0
fm	min	**63.285**	103%	**4.480**	102%	**0.156**	43%	**-2.344**	103%	0.0
2014-02-04	min	**53.492**	85%	**4.378**	98%	**0.232**	149%	**-2.648**	113%	0.0
2014-02-05	min	**57.868**	108%	**4.454**	102%	**0.211**	91%	**-2.747**	104%	0.5
2014-02-06	min	**58.320**	101%	**4.429**	99%	**0.145**	69%	**-2.619**	95%	0.0
2014-02-07	min	**63.916**	110%	**4.447**	100%	**0.211**	146%	**-2.989**	114%	0.5
2014-02-08	min	**65.104**	102%	**4.450**	100%	**0.247**	117%	**-2.813**	94%	0.0
2014-02-09	min	**62.215**	96%	**4.433**	100%	**0.156**	63%	**-2.776**	99%	0.0
2014-02-10	min	**64.082**	103%	**4.428**	100%	**0.126**	81%	**-2.582**	93%	0.0
2014-02-11	min	**61.700**	96%	**4.408**	100%	**0.086**	68%	**-2.381**	92%	0.0
2014-02-12	min	**57.871**	94%	**4.406**	100%	**0.156**	181%	**-2.080**	87%	0.0
2014-02-13	min	**61.268**	106%	**4.453**	101%	**0.156**	100%	**-2.004**	96%	7.0
2014-02-14	min	**n**	-	**n**	-	**n**	-	**n**	-	0.5
2014-02-15	min	**n**	-	**n**	-	**n**	-	**n**	-	0.0
2014-02-16	min	**n**	-	**n**	-	**n**	-	**n**	-	6.0
2014-02-17	min	**n**	-	**n**	-	**n**	-	**n**	-	0.0
nm	min	**114.202**	-	**4.521**	-	**0.789**	-	**-2.857**	-	0.0
2014-02-19	min	**80.682**	71%	**4.402**	97%	**0.533**	68%	**-3.124**	109%	5.0
2014-02-20	min	**10.022**	12%	**4.445**	101%	**0.676**	127%	**-2.916**	93%	1.0
2014-02-21	min	**46.276**	462%	**4.307**	97%	**1.009**	149%	**-2.967**	102%	1.0
2014-02-22	min	**47.257**	102%	**4.496**	104%	**0.921**	91%	**-3.348**	113%	7.0
2014-02-23	min	**95.609**	202%	**4.491**	100%	**0.936**	102%	**-3.011**	90%	1.0
2014-02-24	min	**123.550**	129%	**4.497**	100%	**1.115**	119%	**-2.560**	85%	0.0
2014-02-25	min	**128.198**	104%	**4.426**	98%	**1.060**	95%	**-2.395**	94%	2.0
2014-02-26	min	**130.466**	102%	**4.397**	99%	**0.936**	88%	**-2.564**	107%	5.0
2014-02-27	min	**86.083**	66%	**4.350**	99%	**0.548**	59%	**-1.710**	67%	0.0
2014-02-28	min	**84.797**	99%	**4.404**	101%	**0.441**	80%	**-2.212**	129%	2.0

Fig. 2.10e
February survey, by the author.





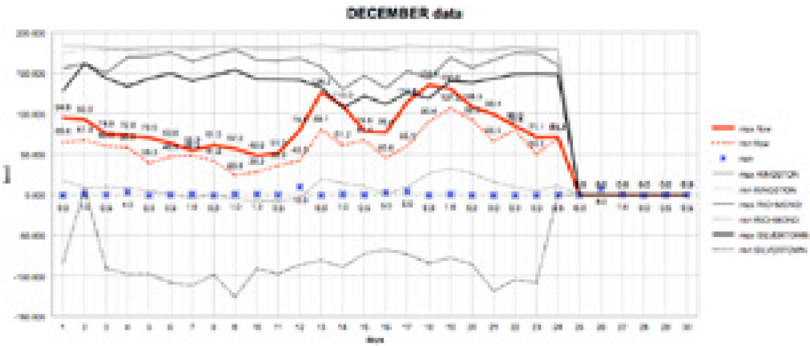
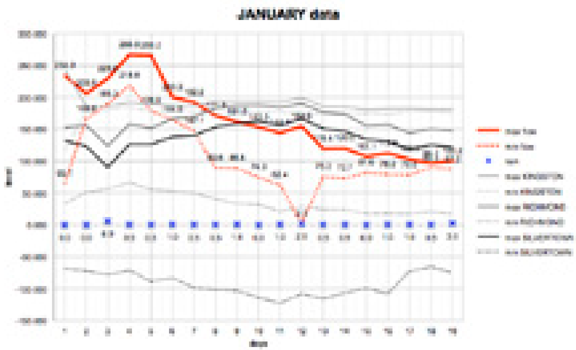


Fig. 2.11a



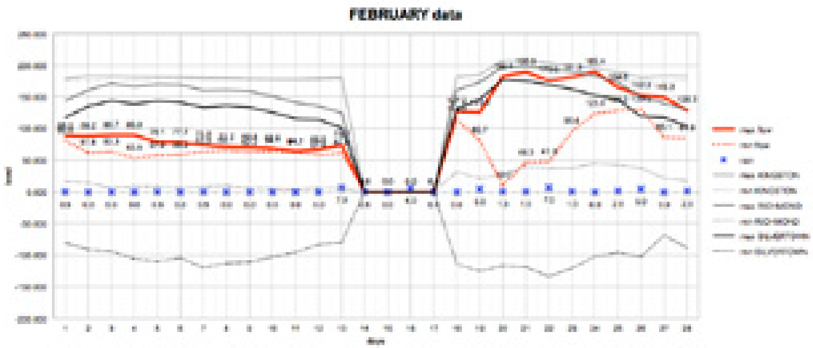


Fig. 2.11
Graphics of the October 2014 to February 2015 survey, by the author.

Data collected in the survey: a. maximum and minimum water levels at Kingston (Teddington), Richmond, and Silvertown; b. the maximum and minimmum flow at Kingston; c. daily precipitations.
Please note for the whole survey: values are mAOD (for meters relative to the Ordnance Survey datum)—the stations analysed—, mASD (for meters relative to the local stage datum)—usually for the forecasts, http://www.pla.co.uk/Safety/Tide-Tables—, m (for meters with an unspecified datum) and m3/s (for flow rates). *Ordnance datum (mAOD) is based on the MSL at Newlyn. (http://environment.data.gov.uk/flood-monitoring/doc/reference#individual-measure)

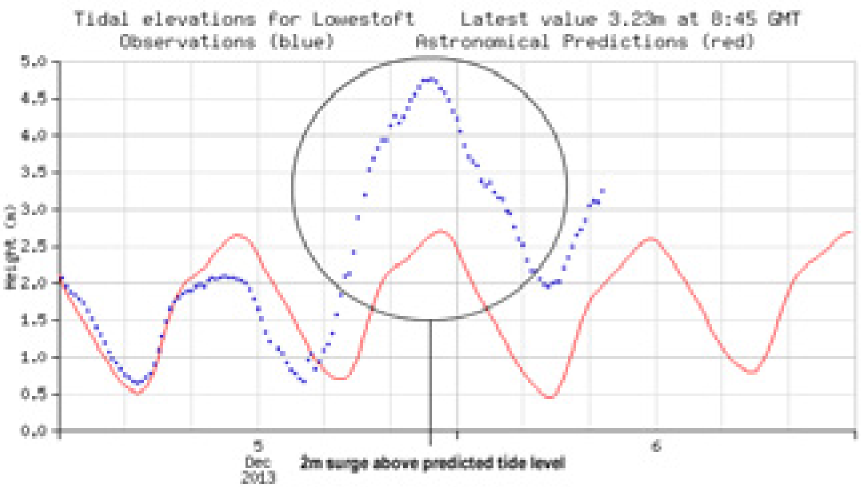


Fig. 1.12
Predicted and observed tide elevations at Lowestoft (Suffolk) on 5th to 6th December 2013.
The surge was 2 m above predicted high water and coincided with high tide.
(Met Office, 2013)

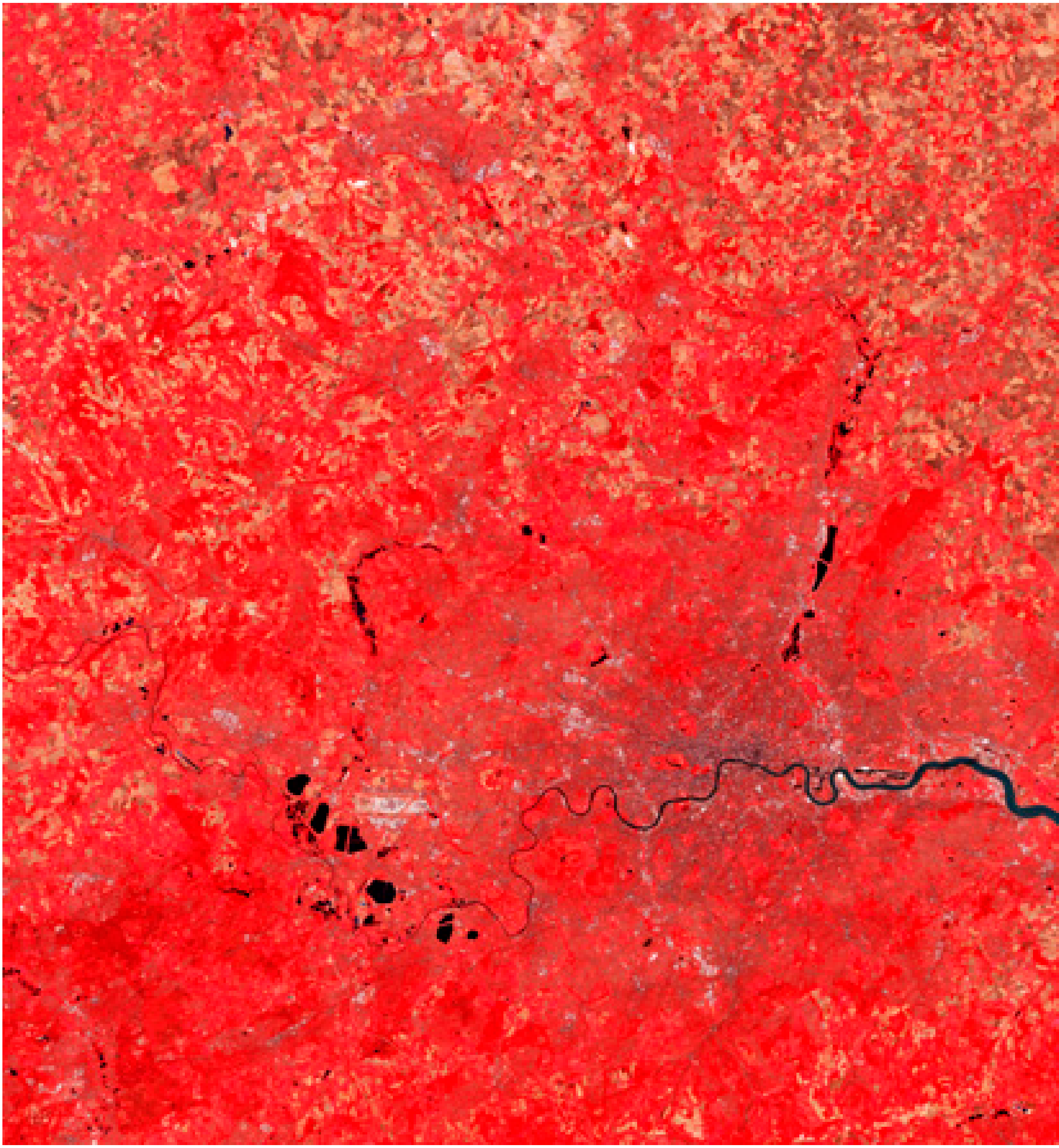
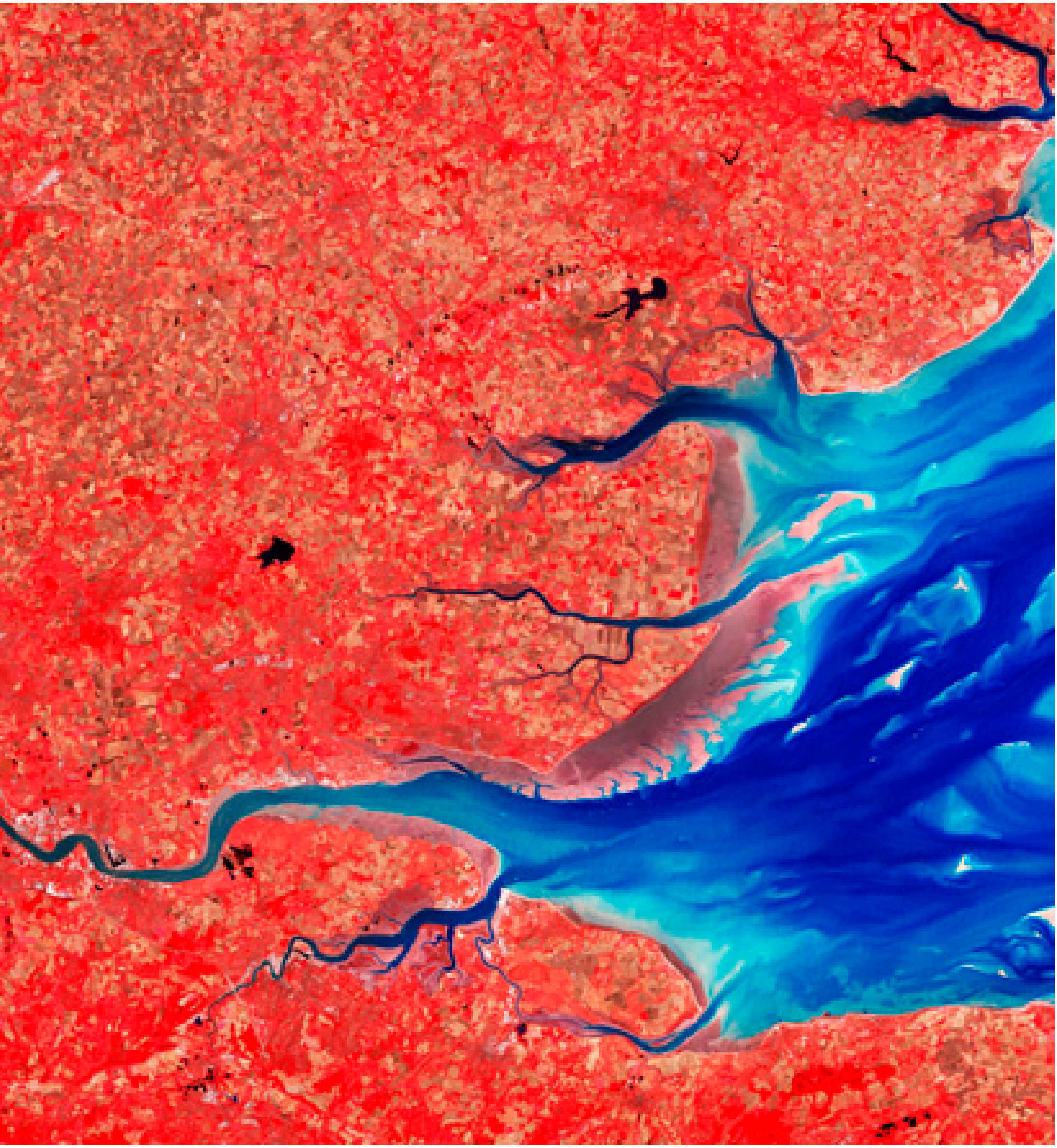


Fig. 2.13
River Thames, elaboration of NASA satellite photograph



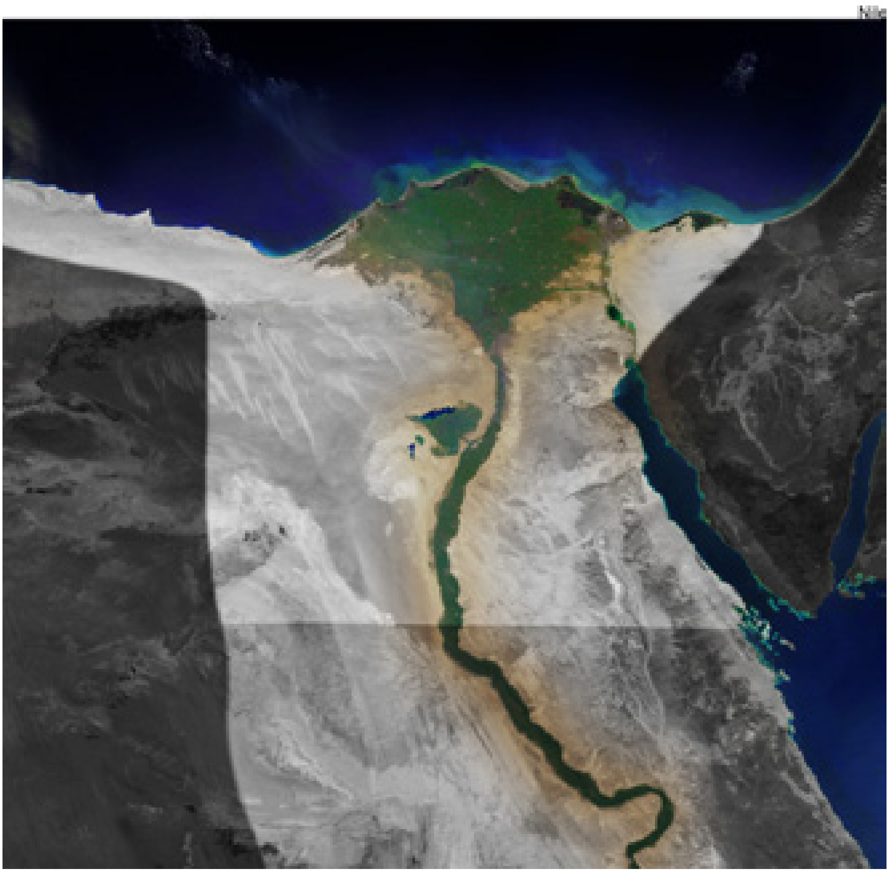
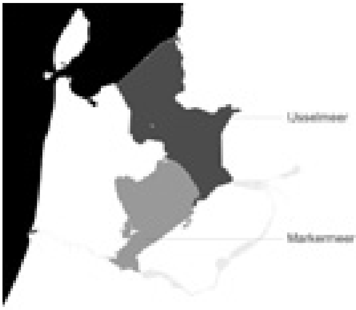


Plate 2.2
Nile River - Egypt (Delta and Ancient Lower Egypt area).



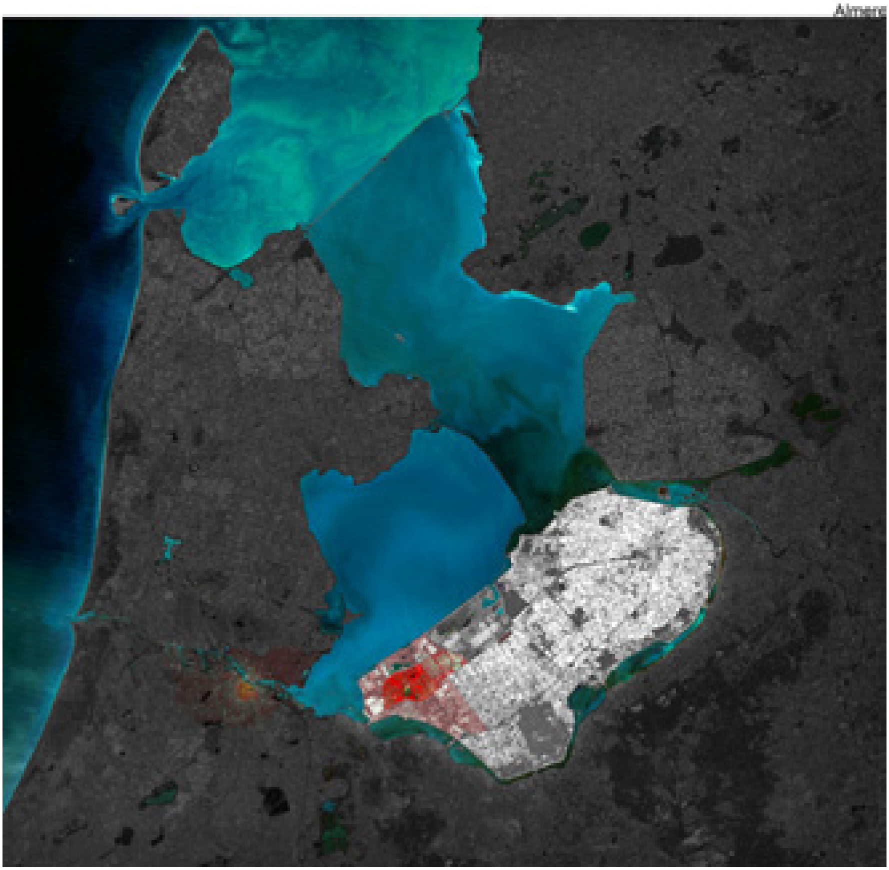


Plate 2.3
IJsselmeer and Markermeer - Netherlands (the Oostelijk and Zuidelijk Flevoland polder is highlighted).

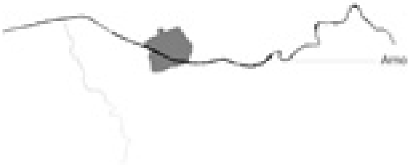


Plate 2.4
Arno River - Italy (Florentine area).

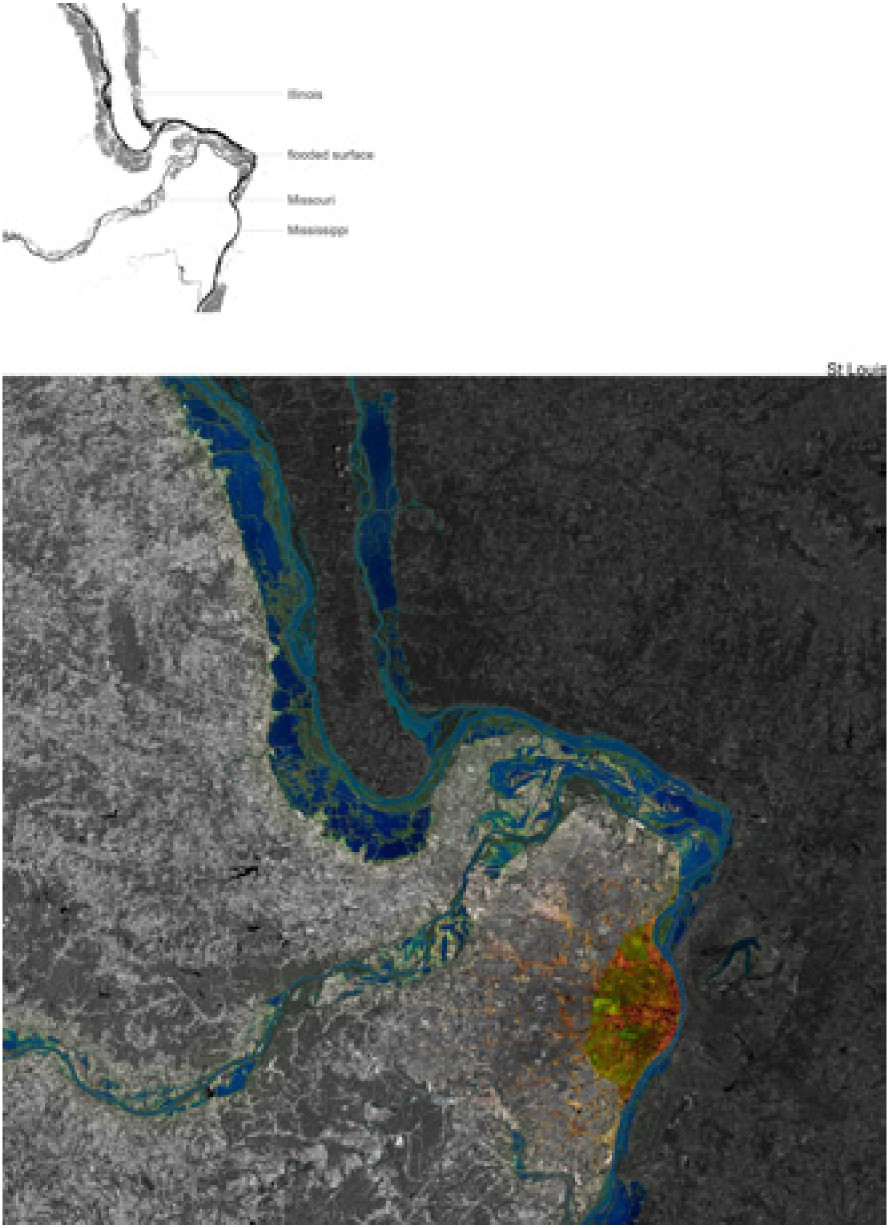


Plate 2.5
Flood of the Mississippi and Missouri Rivers - U.S.A. (St Louis is highlighted).

Notes

[1] List by the Author of the main floods with more than 10 deaths of the least 10 years; then the main floods of the last 50 years for each year; finally the most crucial ones.

2015 - Georgia - flood - 20 died
2015 - Chile (Northern) - floods and mudflows - 150 died
2014 - India - floods - 400 died
2014 - Bulgaria - floods - 16 died
2014 - Serbia, Bosnia and Herzegovina, Croatia - floods - 80 died
2013 - China (South-western) - flood - 250 died
2013 - Italy (insular) - flood - 16
2013 - India (Northern) - floods - 5,700 died
2013 - Argentina - floods - 75 died
2013 - Pakistan & Afghanistan (Eastern) - floods - 187
2012 - North Korea - floods - 223 died
2012 - Russia - flood - 172 died
2012 - Nigeria - floods - 72 died
2012 - Japan - flood - 32 died
2011 - Asia (South-eastern) - floods - 1,828 died
2011 - Philippines - floods by tropical storm - 1,268 died
2011 - Thailand - floods by monsoons - 815 died
2011 - Brazil - floods and mudslides - 894 died
2011 - China - floods- 307 died
2011 - Africa (Southern) - floods - 141 died
2010-11 - Queensland - floods - 48 died
2010 - Pakistan - floods by monsoons - 1,800 died
2010 - Brazil - floods - 246 + 85 + 51
2010 - Colombia - floods - 172
2010 - Pakistan & India - flood - 125
2010 - Poland & Hungary - floods - 37 died
2010 - France - floods - 25 died
2009 - Philippines - floods - 244 died
2009 - El Salvador - floods and mudslides - 199 died
2009 - Saudi Arabia - floods - 123
2009 - Italy (Insular) - flood - 36 died
2009 - Turkey - flood - 31 died
2008 - India - floods by monsoons - 2,400 died
2008 - China (Southern) - floods - 200 died
2008 - Indiana - floods - 16 died
2007 - North Korea - floods - 610 died
2007 - Africa - floods - 353 died
2007 - Indonesia - floods and landslides by monsoons - 119 died
2007 - China - flood - 535 died
2007 - India - flood - 1,103 died
2006 - Philippines - floods and mudslides - 1,144 died
2006 - Ethiopia - floods - 705 died
2006 - Africa (Eastern) - floods - 342 died
2006 - North Korea - floods - 844 died
2005 - China - flood - 1,624 died
2005 - India - flood by monsoons - 1,503 died
2005 - Louisiana - flood by infrastructural collapse - 69 died
-
2004 - Haiti & Dominican Rep. - floods - 3,363 died
2003 - Indonesia - floods and landslides - 313 died
2002 - China - floods - 1,532 died
2001 - Algeria - floods and mudslides - 827 died
2000 - Mozambique - floods - 800 died
1999 - Venezuela - floods and mudslides - 20,006 died
1998 - China - flood - 3,656 died
1997 - Poland & Czech Rep. - floods - 98 died
1996 - China - floods - 2,775 died
1995 - China - floods - 1,437 died
1993 - Nepal, India, Bangladesh &

Pakistan - floods by monsoons - 3,084 died
1993 - American Midwest (Illinois & Missouri) - flood - 32 died
1992 - Afghanistan - flood and mudslides - 3,000 died
1991 - China - floods - 1,437 died
1990 - South Korea - floods - 114 died
1989 - China - floods - 3,814 died
1988 - Bangladesh - floods by monsoons - 2,379 died
1987 - Bangladesh - floods by monsoons - 2,055 died
1985 - Italy - flood by structural collapse - 268 died
1983 - Peru - floods and landslides - 364 died
1982 - Peru - floods and landslides - 532 died
1981 - China - flood - 2,075 died
1980 - China - flood - 6,200 died
1979 - India - flood by structural collapse - 5,000 died
1978 - India - flood by monsoons - 3,800 died
1977 - Pakistan - flood - 848 died
1975 - China - flood by structural collapse - 86,000 died
1974 - Bangladesh - floods by monsoons - 28,700 died
1973 - Spain - flood - 272 died
1972 - South Korea - flood - 672 died
1971 - Vietnam (Northern) - floods - 100,000 died
1970 - Brazil - flood - 172 died
1969 - Tunisia - floods - 540 died
1968 - India - floods by monsoons - 4,892 died
1967 - Japan - floods - 517 died
1966 - Brazil - floods and landslides - 437 died
-
1963 - Italy - flood by structural collapse - 1,909 died
1962 - Germany - flood by storm - 315 died
1955 - India - floods - 1,700 died
1954 - China - floods - 30,000 died
1954 - Iran - floods - 10,000 died
1949 - Guatemala (Eastern) - floods - 40,000 died
1943 - India - floods 10,000 died
1938 - China - floods - 650,000 died
1935 - China - floods - 142,000 died
1928-31 - China - floods - 3,700,000 died
1927 - American Midwest (Illinois & Missouri) - flood - 246 died
1911 - China - floods - 100,000
1887 - China - floods - 2,000,000
1824 - Russia - flood - 10,000
1717 - Netherlands, Germany, & Denmark - floods from storm - 14,000 died
1634 - Germany & Denmark - flood - 15,000 died
1530 - Netherlands - flood by storm - 100,000 died
1421 - Netherlands & Belgium - flood by storm - 100,000 died

[15] Main measure data:
 - datumType: For level measurements this indicates the type of reference point the level is measured from. Can be relative to the Ordnance Survey datum (rt:AOD), to a local stage datum (rt:ASD) or rt:BDAT (below datum?). - parameter: Short, cannonical, name of the quantity being measured e.g. "level", "flow" or "temperature". - qualifier: A qualilfier for the quantity being measured. Most common use is to separate level measures which occur at the top ("Stage") or bottom ("Downstream Stage") of a sluice or weir. - unitName: A name for the units for this measurement including the datumType. Typical values are mAOD (for meters relative to the Ordnance Survey datum), mASD (for meters relative to the local stage datum), m (for meters with an unspecified datum) and m3/s (for flow rates).

Learning from the future

Instant time and open data 2.2.1

> "Big data is all about seeing and understanding the relations within and among pieces of information that, until very recently, we struggled to fully grasp"[1].

The world is overstocked of information than ever before, and this is growing increasingly in future. The variation of scale led at the beginning of the 21st century to a mutation of state: quantitative changes have been driving to qualitative changes. (Qualitative changes do not determine quantitative variations, while a mutation in quantity could cause qualitative changes. See Ch. 0.3.) The research of totality (M.Foucault, 1994) has currently been replaced by limits determined by different kinds of data. The first step concerning the innovation in the relationship between ICT and society—i.e., mapping territory—is about the faculty to extract data from sources capable to give quantitative information. They are provided by open sources and Agencies that are substantially diverse. Indeed, data property is one of the main issues in urban management. To process a series of data implies the capability of transforming it into information, whose record is one of the elements of discrimination between primitive and advanced societies.

Since mathematics enabled data to be analysed and not just retrieved, it was possible to take information generated for a specific purpose and

[1] Mayer-S. V., Cukier K., 2013, *Big Data. Live, Work, and Think*, John Murray, London; p. 19.

turn them into something else. Data processing is a scientific practice dated back to the period of Galileo Galilei. Indeed, at that time phenomena started being analysed and specified according to quantifications and replicability, instead of just logic inductions based on watching. The digital revolution entails the need to transform real data into digital information.

As computer and digital techniques have greatly accelerated feedback collection, we must need to reconsider the role of maps, and the meaning of mapping. Even though ICTs are increasingly reducing the instant time—making maps closer to physical reality—, maps are always a representation, and not the territory itself (J.L.Borges, 2004). That is why we need to analyse data, and not just collect them, in order to shape design as a process instead of a simple automatic result.

datafication *is a technological trend turning many aspects of our life into digital data and transforming this information into new forms of value. It is characterised by the interaction between digital and physical objects and mass customisation of products, and services for — and by — end-users, process automation and efficiency improvements.*

Since ***datafication*** is growing fast and computers can store far more data than a few years ago, the change of scale has headed to a world of perpetual data-driven predictions. Data is not static anymore, and its vast amount of information is creating new correlations between phenomena, because of which we may not be able to fully explain some meaning behind our choices—or at least not at the beginning. Until the end of the last century, before start storing data from any dataset one had to make some decisions *a priori*. In fact, the identification of a scale was crucial to determine how vast the collection should have been; the definition of the topic was necessary to give the research a boundary; and the delimitation of the subjects was fundamental to obtain purer information. Nowadays analysts store everything and 'do a *post-facto* query' (A.Waitman, 2013).

Nowadays, this big data world provides analysts and organisations that collect information a certain level of uncertainty, being not sure what correlations will be produced. One can gather as much data as he may need, mainly depending on the storing capability, and then he can decide what he is looking for. This new methodological process is very contrasting with the common idea to know exactly *where* and *what* to look for. But the correlations may not tell us precisely *why* something is happening, but they alert us that *it is* happening. This does not mean to collect all the data one can pick up with no perspective at all. It is no longer productive to determine rulings about the matter of the sampling. Datasets are indeed far to wide for such limitations, and moreover the reality is too complex to be dissected in fields of hypothesis. The priority is to identify some research boundaries, based on specific criteria variable on the kind of analysis, which will not limit the unforeseen causalities. In this way, one can start with an hypothesis, but he is open to any future scenario.

Predictions deriving from correlations are the heart of big data, as they are representing how behaviours are going to vary over time. But correlation does not entail causation: reality is the real model to test on, i.e. the physical platform for digital and physical data. Real-time data represent s an evolving scenario that is the dynamic model on which future phenomena are materialised, and that must be constantly validated. To set phenomenon variations onto a map is thus extremely important in order to use it as navigational tool. That is, being able to understand phenomena and anticipate their aftermaths through the definition of the trajectory they are taking in a very specific instant, defining the level of risk. In the light of the different perspective the mapping process has undertaken, the very notion of «risk» joined the definition of «territory».

Individual and collective human behaviour are going to take great benefit from a better understanding of phenomena anticipation, and its consequences. The preparedness of the entire community must rise to lower the level of risk, and thus to make more tangible and sustainable the use of new technologies, and to create a more inclusive democratic environment. But the strategy cannot be local to foster a global anticipatory process, and have to create a network to be prolific. Telematic infrastructures establish anticipations of what to expect, and consequentially they 'enable the organism to actually perceive the expected information'[2]. In fact, behaviours are essentially regularly goal-oriented instead of being stimulus-driven, and this can drive to proper decision-making. If behaviour is indeed goal-oriented, this entails that its mutations are refined by the community-system's identity. Anticipation is based on decision-makers that observe and manage the system itself. Appropriate analyses and correct targets can lead to a different design process, connected to people's common behaviour rather than just trying and change it.

In the perspective of territorial management and use of data in decision-making processes, cities are not complete in themselves. This is true, as catastrophic events—and their related risks—are not able to recognise manmade urban boundaries. Moreover, it is not correct to collect data just for the most fruitful urban areas, considering the countryside (and often also the hinterland) as different and alien parts of cities. This is even more evident considering that vary outsider agencies, universities, industries, sponsors, etc. are consulted for creating strategic platforms. The predominance of big industrial and financial groups over decisions about strategic policies is a risk that is dejected by ICT, which determines the potential

[2] Riegler A., 'Dualism vs. Non-dualism', in L'Abate L. (ed), 2012, *Paradigms in Theory Construction*, Springer Science+Business Media, Berlin, p. 241.

growth of people's participation. This bottom-up decisional process does not foster a hyper-democratisation that often drastically slows the process itself, since it is a real-time event—being driven by open data. Telematic platforms would shift decisional acts from traditional central administrations to research and university centres specialised in complex data analysis. That means to have more coherent and precise planning outcomes. In so doing, the risk of mono-directional top-down solutions lead by technologic determinism would be removed as well.

The possibility to collect users' geolocation data has great value. We can know almost real-time where people are, and understand their behaviours. This has a meaning that goes far beyond rendering attitudes and study behaviours; it has to do with future mass phenomena and social changes. To see the world as a sum of data and information to analyse and explore in depth offers us a view on a future reality, whose perspective was veiled, or invisible before.

As an aside, we have to clarify the relation between data and information. Data is raw material, which needs to be processed to be turned into something useful. Data manipulation is thus a form of design, and it is the mere reason why the architect is entitled to enter digital fields. Inventing the ***World Game*** in 1961, R.Buckminster Fuller designed a global field where all the players need to gather better data than the counterpart, and convert them into useful political information. They also need an information source capable to control the real-time conition of the world, catching essential new information onto the global platform. To simply collect and store data of many forms—numbers, words, symbols, etc.—is not very useful on its own. Through data processing one can transform this rough matter into information. This is meaningful to the person that receives it. To have gathered data does not imply being able to translate them into valid information. Alan Turing was just in possession of vast amount of letters and numbers, before completing 'the bombe', the cryptanalytic machine capable to convert the apparent illogical sequence into information, a message of full sense. Information is the name for the content of what is exchanged with the outer world.

World Game *is an educational simulation based on the Dymaxion Map, developed to help create solutions to overpopulation and the uneven distribution of global resources.*

The immediate value of data is as important as the historical ones: its benefits do not diminish over the time, and neither once they are used. Like data, information generally does not undergo any sort of decay either. Furthermore, as data can be utilised several times for the identical purpose, it can also be used for many different intentions. In the next chapter and in Chapter 3.1.2, the re-use of data for different purpose will be investigated. Data can shift from primary to secondary uses, from a field to another that has nothing to do with the original one. Important information can only be released by interweaving different datasets.

Technological transfer to architectural design process 2.2.2

The importance of understanding how data works and how they can be combined together is important not just to identify its management during the gathering phase, but also to determine their processing aspects. *Datafication* necessitates much more than simply spreading sensors around the city, and requiring new business for the management of data. Firstly, it requires governments to grasp innovative analytic systems and dynamic dashboards to fully comprehend the value of data, and to try and find new correlations. Secondly, decision-makers have to combine the skills of designers, programmers, and statisticians. It is thus a big change in the whole governance system, and in its actors' know-how.

Pathfinders in the big data world often come from totally different sectors of research and analysis, or from other specific industries. Nonetheless, architects are quite intractable to contemporary updates: their refusal to embrace technological innovations invites their extinction (D.Celanto, 2007). Albeit information and communications technologies provide architects a profound renovation and new prospects for the design process, the plunge into real estate confines innovation within static domains. Professionals and specialists find often difficult to withdraw traditional ideas and working system. To avoid being relegated as exterior stylists, architects have to expand their skills by taking advantage of emerging technologies.

In the field of strategic urban planning and architectural design—these subjects cannot be disjointed for their intrinsic nature—the technological transfer is not confined to the only act of including something that is not specific to the discipline. The very meaning of the term is to create a network of different sources from which to take great benefits, and to which wide benefits are given. Networking implies to render a more complex and complete reality.

The lack in considering the realty as a whole dynamic system causes two interrelated issues to urgently deal with. a) The serious defect of looped feedbacks make analyses incomplete, and actions limited in terms of efficiency and *futurability*. b) One-off disconnected virtuous cases are the negation of the **economies of scale**, and weaken the integration of new

economies of scale *are factors that cause the average cost of producing something to fall as the volume of its output increases.*

technologies a lot.

Keeping in mind the definition of technology of the prologue (see Ch. 0.1), the many aspects of transfer to urban planning and architectural design can be divided into three main fields, as follows:

1. Digital technology
2. Geospatial analysis
3. Physiography

These three categories plays a complementary role in the development of this dissertation. *Digital technology* grounds the methodology; *geospatial analysis* provides the tools; *physiography* supplies knowledge. Architecture is thus the answer. It is the actions springing from these sources, and the real spine that drives all the research.

1. *digital technology*. To 'be contemporary' means to become contemporary, i.e. to make things being happening at the present time. While a hundred years ago it meant to trace the final state of perfection, now it means a mechanical collection, 'with no final state in sight' (Z.Bauman, 2005). The nearly obsessive need of the last five decades of narrowing the time between instants helped the data-use simplification process. Digital information enables vast amounts of data to be easily stored and used, and digitalisation makes any form of transmission faster than ever before. The term 'digital technology' comprehends the use of digital resources, and their analyses and communication in any computerised context. It creates a virtuous circle of perpetual advancement fostered by continuous feedbacks.

Digital technology is the basilar ground of the research, as data gathering needs a flexible platform to be analysed. Medias build up opportunities for many kinds of connections between communities and the places where they live, and create flows of information, communication and knowledge. Medias, collective communication outlets, tools, and devices, are used to store and deliver data. These provide the matter for investigations, through which process social, environmental, and physic behaviour emerges. Communications and interactions within urban entities can then transform forms of social involvements in specific public contexts, such as spatial mobility and the real estate. Many cities 'around the world are rapidly evolving under the aegis of ubiquitous computing [...][3]'. Now is the time to

[3] Geiger J., et al. (eds), 2013, *MediaCities*, Departments of Architecture and Media Studies, the University at Buffalo, State University of New York, p. 6.

recognise and identify new models, problems as relevant to all cities.

2. *geospatial analysis*. Today we may leave the opposition between landscape and urban to the past. The environment and communities must be seen as interwoven ecologies. The question now is the understanding of the roles of digital media within the whole environment. For example, the matter of scale assumes a crucial relevance, as we are dealing with scalar geographic elements of the environment, and non-scalar entities, as data and information, which are local and global in scale at the same time. This issue challengly engages spatial, social, ecological and technical implications as one try to create a global platform based on digital technologies.

GIS analysis has been leading to new tools to describe the distribution of many entities within a certain territory, and then discern patters and calculate relationships. Geospatial analysis allows extracting specific answers, in order to make strategic decisions. The platforms necessary to conduct these studies are digital maps, which guarantee a high level of inter-operability. They collect data and format them into a virtual representation. Geospatial analysis helps to identify current phenomena, and to predict future ones through the institution of information relationships. Moreover decision makers are able to verify their conclusion by digital simulations on highly accurate models. These are built on data extracted from the observation of physical events.

3. *physiography*. The cognisance of nature and the awareness of different dynamics of natural events empower the full understanding of the territory where one community is settled. Physiography, the branch of natural science that studies processes and patterns in the natural environment[4], is one of the main sources of information. For this research, it provides data regarding the sub-branches of geomorphology, hydrology, glaciology, climatology, meteorology, and environmental geography. Mainly coming from public and private Agencies rather than ordinary people, digital data can be easily found on monitoring and forecasting website, and online dashboards. Further analyses and application to physiography lead to the management of problems related to global phenomena. Advance in technology has induced the development of many devices to monitor Earth resources and the environment.

In this dissertation, physiography—physical geography—shall be related to human geography as complementary aspects of the same reality,

[4] Pidwirny M.J., 2006, *Fundamentals of Physical Geography*, http://onlinebooks.library.upenn.edu/webbin/book/lookupid?key=olbp36885

i.e. the territory. Thus, maps are the only spatial support capable to host many data and information characterised by different spatial features, and heterogeneous sources. Human behaviours, the landform, rivers flow rate, green areas, etc. shall find their relational meaning within the same map.

Notes

Being always, at any stage and at all times, ‘post-something’ is also an undetachable feature of modernity. As time flows on, ‘modernity’ changes its forms in the manner of the legendary Proteus. What was some time ago dubbed (erroneously) ‘post-modernity’ and what I’ve chosen to call, more to the point, ‘liquid modernity’, is the growing conviction that change is the only permanence, and uncertainty the only certainty. A hundred years ago ‘to be modern’ meant to chase ‘the final state of perfection’—now it means an infinity of improvement, with no ‘final state’ in sight and none desired.

Bauman Z., 2005, *Liquid Life*, Polity Press, Cambridge, UK

[4] Geography is a discipline that integrates a large variety of fields. Basically any sector of human knowledge can be analysed from a spatial perspective. The main subdisciplines of geography are human and physical geography. Physical geography studies the Earth’s atmosphere (meteorology and climatology), animal and plant life (biogeography), physical landscape (geomorphology), soils (pedology), and waters (hydrology). Human geography is about human society and culture (social and cultural geography), behavior (behavioral geography), economics (economic geography), politics (political geography), and urban systems (urban geography).

Mapping

Excursus on maps 2.3.1

«Mappa» is a Latin word of Punic origin that means «tablecloth», «napkin». It generally was a drape made of flax, which was used to wrap, and then carry the leftovers of the meal away. They were coloured purple and gold, and embroidered with reproductions of foods and dishes. The current meaning comes from the use of flax drapes to draw geographic and topographic charts too. So, «map» became the word referring to a two-dimensional depiction of a portion of the territory, and then the entire surface of the globe. Travellers, explorers, and scientists have always been trying to represent their worlds, tailoring the maps on their needs and aims. They look objective and authoritative, even though they are not: they often unvail information about their cartographers rather than the realm they are supposed to detail.

The representation of the surface of the world had been one of the first strongest ways to understand the vary aspects of the Earth. The first maps that have survived to this day are carved in stone, and shows villages or parts of them. Nevertheless, the oldest were realised to trace out routes and show environmental resources on different materials, such as ceramic, bark, leather, papyrus, bronze plates, and—as said—flax drapes. The oldest map found is a scratch-work on mammoth tusk from Mezhyrich, a village in Ukraine, which represents an encampment next to a river. It is dated back to the 15th millennium B.C.[1] In Çatalhöyük, southern Anatolia, the first plan was found as graffito on stone, dated back to 6200 B.C.[2] The highly detailed drawing shows about eighty houses gathered in blocks, streets, and the surrounding landscape, including an erupting volcano. The geometric representation improved a lot in the most evolved civilisations, as proven by the Mesopotamian City Plan for Nippur of the 1500 B.C. On the clay tablet, the main temples, the city wall with its seven gates, and the city park are engraved. Also the River Euphrates and two canals are shown, and several structures contain measurements in units of twelve cubits (about six meters)[3]. To present date, this drawing is the earliest plan drawn to scale, as proven by the comparison to contemporary maps.

The first map of the Earth, known as the Babylonian Imago Mundi (c. 600 B.C.), represents Babylon encircled by Assyria, indicated north-east of Babylon; Urartu (Armenia), indicated north of Assyria; and the land of Habban (South Yemen), indicated south-west of Babylon[4]. These are surrounded by the 'bitter river', the Ocean, framed within two concentric circles. The continent contains some topographic features, such as mountains in the north, from which the Euphrates originates, running towards the marshes at the bottom of the map. The text contains the description of distant regions on both sides of the stone, depicted as triangular islands rising beyond the ocean. The seven cities of Mesopotamia are the very heart of the globe, a flat surface ringed by water. The map has a specific orientation, which is not based on the cardinal points, but is based on the prevalent winds, with Northwest at the top. The Babylonian map is an ideograph of a cosmologic vision[5] that reveals the aspiration to a wider geographic consciousness, and to beat the limit of the visible horizon.

It was the contribution of nomadic population and travellers to better define routes and geographical features. Then, the need of conquering new regions, and the circumnavigation for trade raised the importance of cartography. The Hellenistic culture and the establishment of the Mile-

[1] Hoffecker J., 2002, *Desolate landscapes: Ice-Age settlement in Eastern Europe*, Rutgers University Press.

[2] Mellaart J., 1964, *Excavations at Çatal Hüyük, third preliminary report*, Anatolian Studies, vol. 14, pp. 39-120.

[3] Catizzone A., 2007, *Fondamenti di Cartografia*, Gangemi Editore, Roma, pp.18,19.

[4] Raaflaub K.A., Talbert R.J.A., 2009, *Geography and Ethnography: Perceptions of the World in Pre-Modern Societies*, John Wiley & Sons, p. 147.

[5] Catizzone A., Nunziata R., 'Semiologia e simbolismo nella rappresentazione cartografica'. In 1995, *Disegnare*, n.11, p.68.

Fig. 2.14
Carta Pisana, parchment, 1050x500 mm, about 1275-1300 - Paris, Bibliothèque Nationale de France.

sian school of the 6th century B.C. developed an increasing interest in the refinement of the graphic representation. In contrast to the Homerian philosophy, Pythagoras was the first to support the sphericity of the Earth, and then Aristotle confirmed his hypothesis with theoretical proofs, and the calculation of the inclination of the terrestrial axle. Plausibly Eratosthenes, the chief librarian at the Library of Alexandria, was the first to measure the circumference of the Earth, in the 2nd century B.C. He obtained the surprising value of 250.000 stadia[6], 39,395 kilometres, less than 2 per cent off the actual Earth's circumference of 40,009 kilometres (24,860 miles), if he used the Egyptian measurement system. Eratosthenes also contributed in evolve the cartographic method through the creation of a grid for a more correct positioning of places.

Thanks to Marinus of Tyre, who defined the equirectangular projection, and the latitude and longitude based on degree of arc, Claudius Ptolemy gave more than seven thousand cities their geographic coordinates. In the 2nd century A.D., with the publication of *Geographia*, he also represented twenty-six maps of the areas of Europe, Asia, and Africa reached by the Roman Empire. He has the great merit of indicating how to project the sphericity of the globe onto a plain surface. His studies and drawings had been considered with great respect throughout the entire Roman period, when the main issues were the land register, and the Middle Ages, until the end of the 13th century.

Considerable progress was made, as trade and commerce required it, after the end of the Arabic influence on the Mediterranean Sea. The primary need was to know the distance between harbours, on he basis of routes already reported through the cardinal directions, or the wind compass. The oldest so-called 'portolan chart' is the *Carta Pisana,* dated about 1275-1300 (Fig. 2.14). It shows a detailed study of the coasts of the Mediterranean Sea and the Black Sea, and approximately also the eastern Atlantic Ocean, without any indication regarding the topography and the toponymy of the inland. In contrast to the coeval maps, North is on the top. The map circumscribes almost the entire Mediterranean inside two circles. These inscribe four systems of square, divided into sixteen parts, providing each one the corresponding wind directions.

Since the end of the 15th century, the further developments of cartography depended directly from the European explorations of the 'New Worlds'. The voyages of Bartolomeu Dias (1487-88) and Vasco da Gama

6 Gow M., 2010, *Measuring the Earth: Eratosthenes and His Celestial Geometry*, Enslow Publishers, Berkeley Heights, p. 6.

(1497-98), who reached India circumnavigating Africa, and then the ones of Cristoforo Colombo (1492 to 1504), Amerigo Vespucci (1497 to 1504), and Ferdinand Magellan (1519-21), who reached the America, determined new geographic knowledge. The 16th century is the golden age of maps: beside the parchment commonly used, atlases and highly detailed printings—at that time printing started being diffused also to cartography—were circulating over Europe. Many updates to charts were developed, and the distinction between nautical and geographic maps started to ease, as they increased the amount of information about geomorphology, biology, and regarding settlements.

In 1575 the first part of the *Atlas, sive cosmographicae maditationes de fabrica mundi et fabricati figura* by Gerhard Kremer was published. The fundamental chart of this collection, still in use for navigation, was realised through cylindrical projections, and modifications based on mathematical calculations and empirical procedures. The 17th and 18th centuries brought significant scientific advancements thanks to new methods of measurements and geographic location. Willebrord Snellius started the first triangulations of far location in the Netherlands, using trigonometry. Then, the Napoleonic military campaigns (from 1796 onwards) contributed to the detailing of maps. In fact he needed not just the thorough knowledge of precise locations, but also the features of the territory, and its geomorphology. As measure techniques upgraded, also the representation improved considerably, and new colours and symbols were standardised. Even though the Napoleonic aspirations were not entirely realised, his geographic maps had been the base for the 19th-century charts, and most of all for international agreements regarding global standardisation of graphics. Surely the greatest contribution was given by Carl Friedrich Gauß, who formally expressed the mathematical bases of charts theory based on geodesic triangulations.

The International Conference held at Washington in 1884 chose the Royal Borough of Greenwich as prime meridian[7]. Subsequently, the one held in Bern seven years later was intended to realise an International Map of the World on scale 1:1,000,000. The project was never completed, neither in the second attempt dated 1913. Nonetheless, studies and cartographic production increased a lot by single countries, until the most life changing step was made: the *Web*. The *World Wide Web* (W3, or www), the knowledge space where documents and many other web capitals can

7 International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October, 1884; http://www.gutenberg.org/files/17759/17759-h/17759-h.htm

be achieved via the Internet, was born on March 12th, 1989. From this date, the way of mapping the territory changed, and a conspicuous number of developers have been creating their own platform. *Xerox PARC Map Viewer* was launched in June 1993, *MapGuide* in 1995, ArcIMS 3.0 in 2000, *Yahoo! Maps* in March 2002, *NASA World Wind* in 2003, *Open-StreetMap* in July 2004, *Google Maps* and *Google Earth* in 2005, *Bing Maps* in December 2010, and *Apple Maps* in September 2012.

The 20th century represented a radical change for cartographic techniques thanks to the introduction of aerial and satellite photography (Figures 2.15, 2.16, 2.17) in the discipline. The **orthophotos** are then geometrically corrected and registered to be gathered as a map, and vast series of these, usually divided into tiles, are widely used by mapping agencies (e.g. Ordnance Survey, Google Maps, Bing aps). The great complementary revolution brought by digital systems was the perfection of satellite positioning techniques GPS (Global Positioning System). These have opened new scenario on qualitative and quantitative analyses regarding spatial data, which are collected onto digital platforms based on GIS (Geographic Information System). Through GPS and GIS, data is spatially located in accordance with a unified reference system. On maps, GIS data performs as real objects, such as canals, houses, elevations, characterised by intrinsic features. Real objects are divided into two categories: discrete objects, which are discontinuous entities e.g., a house; and continuous fields e.g., the landform and rainfall amount[8].

orthophoto *is a uniform-scale photograph. It is a photographic map on which it is possible to measure directly on it like other maps.*

One of the crucial platform for this research is the Ordnance Survey, the national mapping Agency of Great Britain[9], which produces digital maps, online route plans, shared services, and mobile application softwares. Its geographic dataset is as big as accurate and granular. Each single fixed object in the country is mapped with high accuracy. It is such a dynamic platform, as 10,000 updates a day are provided to the system. On the Ordnance Survey one can also compare different hand-drawn maps implemented over the centuries, and match them to the current satellite one (see Fig. A.1, Annex B, Section A3). This allows gaining important information regarding the evolution of cities, and helps in fully understanding hidden features of the territory.

As previously stated, digital information is the core of modern GIS

[8] Shan G., 2004, 'Flexible Support for Spatial Decision-Making', in Proc. of the 37th Hawaii International Conference on System Sciences, p. 10.

[9] http://www.ordnancesurvey.co.uk Please note that the Ordnance Survey deals only with maps of Great Britain, and, to an extent, the Isle of Man. Northern Ireland, which has its own, separate government Agency, the Ordnance Survey of Northern Ireland, is not included.

Fig. 2.15
The first satellite image shows a sun-lighted area of the Central Pacific ocean and its cloud cover.
The picture was made when the satellite was about 17,000 miles above the surface of the earth on August 14th, 1959.

Fig. 2.16

A NASA camera on the Deep Space Climate Observatory satellite has returned its first view of the entire sunlit side of Earth from one million miles away. This color image of Earth was taken by NASA's Earth Polychromatic Imaging Camera (EPIC), a four megapixel CCD camera and telescope. The image was generated by combining three separate images to create a photographic-quality image. The camera takes a series of 10 images using different narrowband filters—from ultraviolet to near infrared—to produce a variety of science products. The red, green and blue channel images are used in these color images. The image was taken July 6, 2015, showing North and Central America. The central turquoise areas are shallow seas around the Caribbean islands. This Earth image shows the effects of sunlight scattered by air molecules, giving the image a characteristic bluish tint. The EPIC team is working to remove this atmospheric effect from subsequent images. Once the instrument begins regular data acquisition, EPIC will provide a daily series of Earth images allowing for the first time study of daily variations over the entire globe.

Fig. 2.17

Africa is front and center in this image of Earth taken by a NASA camera on the Deep Space Climate Observatory (DSCOVR) satellite. The image, taken July 6 from a vantage point one million miles from Earth, was one of the first taken by NASA's Earth Polychromatic Imaging Camera (EPIC). Central Europe is toward the top of the image with the Sahara Desert to the south, showing the Nile River flowing to the Mediterranean Sea through Egypt. The photographic-quality color image was generated by combining three separate images of the entire Earth taken a few minutes apart. The camera takes a series of 10 images using different narrowband filters -- from ultraviolet to near infrared -- to produce a variety of science products. The red, green and blue channel images are used in these Earth images. DSCOVR was launched in February to its planned orbit at the first Lagrange point or L1, about one million miles from Earth toward the sun. It's from that unique vantage point that the EPIC instrument is acquiring images of the entire sunlit face of Earth. Data from EPIC will be used to measure ozone and aerosol levels in Earth's atmosphere, cloud height, vegetation properties and a variety of other features.

technologies. ***Digitisation*** is one of the most common methods to create data, using CAD programs. The transfer of hard copies and survey plans into digital medium through ortho-rectifying process allows then data to be extracted. These systems use spatio-temporal location as variable for the information. Any variable is thus recorded as x, y, z coordinates of the Cartesian system in a specific date/time. In so doing qualitative and quantitative dynamics and trajectories can be evaluated, interpreted, and represented over time. The functionality of telematic maps has been remarkably improving by the simplification process of superimposing georeferenced entities onto existing geographical charts. Ones local data, such as rainfall, demography, winds, etc., is integrated within the map, one can produce more efficient analyses, and take better decisions.

digitisation *is the process of converting data into a digital format. This digital data is organised into discrete units that can be separately addressed. It is the binary data that computers and many devices with computing capacity can process and analise.*

This relational system—which is ultimately connected to real physical domains—gives the access to incredible sources coming from the past, and projected to the future. It is indeed the most extraordinary feature of contemporary maps: they do not simply represent the past, but also the future. New ranges of scientific inquiry are now opened. Behaviours and patterns of the real world can be discovered, while previously they had not even been correlated. This revolution regards both the way data is collected, and the way information is interrogated.

One can examine the status of the Earth crust and atmosphere by supplying GIS the necessary amount of satellite data. As this technology allows studying global dynamics of our planet and its inhabitants over days, months, and years, it is possible to obtain measures of the relation between phenomena. For example, working with the variable of the ecological conditions of plants, and seasonal rainfall, the regional different effects can be studied. The correlation between several datasets then creates a unified new output, which merges geographic features and their attributes. Hence, both vector and raster information can be extracted, and again combined with other datasets. This shows how important is the ‘second life’ of data, and its continuous re-use. Through the variation and alteration of inputs, the influence of specific factors upon precise phenomena can be understood.

GIS spatial analysis changes quite fast: analytical tools are often updated, and maps get more evolved with them. It is not just the depth of the analyses to improve, but also the kind of them. In the last years, new typologies of maps were born. Some study environmental events, for instance river tides e.g., the *Thames Tideway Online*[10], which shows the current tideway levels in one table with links to graphs. Other analyse anthropogenic phenomena, such as the landscape management e.g., the California state-wide map of working landscape, urban and residential areas, public and private ownership, and reserves[11]. From the map one can see the predominant land use, and evaluate the density of urban areas as compared with the whole State. Most interesting are those maps that study human attitudes and behaviours. Mapping human states is an innovative method to assess behaviour linked to detailed physical features of urban areas. Looking at any context, the aim is to increase the awareness of how any different place predisposes to specific moods and actions. Moreover, the understanding of these conditions must also include other issues, such as the wealth, and socio-cultural differences.

The public sentiment map of the New York City metropolitan area, developed by the New England Complex Systems Institute, measures the patterns of moods analysing data provided by social media. The combination of sentiment ratings with geolocations has led to determine the areas with strong and weak sentiment. These data were also observed throughout the days, in order to create a daily scale. The method of public mood analysis has the important strength of being able to provide spatial information that is both 'wide-ranging' and 'fine-grained', by utilising Twitter's abundance of ***geotagged*** data[12].

geotagging *is the process of adding geographical identification metadata to various media. This data usually consists of latitude and longitude coordinates, though they can also include altitude, bearing, distance, accuracy data, and place names.*

Other interesting digital maps are the ones connecting spatial entities to people's attributes. For instance, the map of the most popular occupation by area in London[13], which shows the way occupations are locally aggregated; and the map of tongues by tube stations[14], which analyses the second most commonly spoken language (after English) that people who live nearby speak within 200 metres radius of the tube station centroid. As large demographic datasets are available as open data—from the 2011 census—, it is now possible to create flexible interfaces that enable detailed explorations of such datasets. This demographic data, studied at the Geographic Department of the University College London, is just an example aimed to state the vast possibilities nowadays opened.

10 http://thames.me.uk/s00030_tideway.htm; http://apps.environment-agency.gov.uk/river-and-sea-levels/136436.aspx

11 http://frap.fire.ca.gov/data/frapgismaps/frapgismaps-management_landscapes_download.php

12 Bertrand K.Z., et al., 2013, *Sentiment in New York City: A High Resolution Spatial and Temporal View*, New England Complex Systems Institute, Cambridge, MA.

13 http://vis.oobrien.com/tube/#metric=wardwork

14 http://vis.oobrien.com/tube/#metric=tongues

The first maps in human history, as well as the most advanced current ones, are always a representation of the reality, and not the reality itself. They have constantly been driven by commercial aims and political interests. Indeed, there is not even a single case in which the mapping process is not focus on a precise ideology: to convert something real into something virtual necessitates having finalities. This concept seems easy to demonstrate, as we look at Harry Beck's 1933 map of the London Tube. Yet, it is harder to get, looking at satellite maps.

> "Classical geography, which was planned-based, conceived cities as physical entities, to be analysed in terms of size, density, land use, population, centricity, axiality, and so forth. [...] It became involved with economic growth, social deprivation, education and the environment. [...] It is recognised that society is contextualised and regionalised around a multi-layered nesting of supra-individual modal locales [...]. [There is] the need for multiple world views, which GIS are eminently capable of managing. Structuralism suggested the need for new world-views; computer-held databases facilitate their representation. Multiple ways of looking at the world will be paralleled by multiple ways of looking at planning and design."[15]

This thesis shall demonstrate how effects—mainly caused by global warming—can be connected to data about people's behaviour in order to better understand future dynamics. These phenomena play a crucial role in mapping the city of tomorrow, as almost any country is involved in increasing magnitude of catastrophes, and plausibly disasters. To make cities prepared means to set a holistic approach to environmental issues: many components of our ecosystem are strictly linked with social, cultural and economical structures of our society. Even though several measures to cope with global warming have been adopted by some countries and municipalities, the common condition is to show certain recognition was gained, instead of ameliorate planning process depending on climate change policies. The reassessment of traditional maps is not sufficient anymore to guarantee continuity in the city planning process.

[15] Turner T., 1996, *City and Landscape. A post-postmodern view of design and planning*, E & FN Spon, London, p.52.

> "These categories [natural – man-made phenomena, earth – sky, and outside – inside] have spatial implications, and «space» is hence re-introduced, not primarily as a mathematical concept, but as an existential dimension[16]. A final and particularly important step is taken with the concept of «character». Character is determined by *how* things are, and gives our investigation a basis in the concrete phenomena of our everyday life-world. Only in this way we may fully grasp the ***genius loci***; the «spirit of place» which the ancients recognized as that «opposite» man has to come to terms with to be able to dwell[17]."[18]

genius loci *in classical Roman religion was the guardian spirit of a place. In contemporary usage, it usually refers to a location's character, and authentic quality, in which people identify themselves.*

Humans have always been trying and expand their knowledge, and break their limits. Since the first space missions were launched, in the 1950s, an increasing consciousness of the planet, and a terrific fascination of the vast universe arose. They have been exploring the entire globe, pretending to be able to keep it under control. It is not even true the farthest one watches things from, the less one knows; indeed current technology allows for a highly detailed vision of things. But the distinction between vision and cognisance still persist. Even though progress is providing useful pictures of the reality, which is not enough. Now humanity has reached such a level of definition, right for this reason the analyses must be more comprehensive and exhaustive.

The advancements in digital technologies applied to geography and urban analysis can give designers and decision-makers the full understanding of the identity of a place i.e., its *genius loci*. They can also provide its projection into the future, leading to a more sustainable strategic vision of sites. The highest level of awareness is thus the match of one place and its *genius loci*. Moreover, digital technologies have led to a new consciousness of immaterial space, which is connected to the material world. Hence there is a second level of space, to which *genius loci* expands to. The awareness is therefore reached as the physical place merges to the virtual one.

The place is the real core of all spatial analysis. People identify them-

16 Norberg-Schulz C., 1971, Existence, Space and Architecture, Studio Vista, London and New York.

17 Heidegger points out the relationship between the words *gegen* (against, opposite) and *Gegend* (environment, locality).

18 Norberg-Schulz C., 1980, *Genius loci: towards a phenomenology of architecture*, Rizzoli Publications, New York

selves with places of disparate areas, heights, and shapes, from their room to their piece of land, to the neighbourhood, the city, and so forth. Places endlessly undergo mutations due to population growth, people's migration, global warming, and many other man-made and natural phenomena. A time would have been difficult to map these dynamic processes that affect each place of the Earth, but nowadays maps can be not simply modified, but connected to a number of devices, so that variation produce nearly real-time changes on a map. It would be misleading to ignore rapid mutation and constant movements that characterise the real world. So, science needs precise data to link to an exact place, for they have to be subjected to spatial analysis, driven by rigorous mathematical procedures. The measurement of phenomena gives back a value characterised by a certain degree of accuracy, from which any further analysis depend. Due to the nature of registering, any decay in survey accuracy, or any loss of scale precision determines a quality decay of information.

As the increasing availability of data is turning information technology into the most democratic field of our global society, a digital spatial intelligence that is giving new shapes to design processes of any field, from business to politics. Moreover, also telematic platforms and devices are easier to be used by anybody. A variety of products provide developers and users flexible software and plug-ins, which can be integrated with one's own variants for analysing data. In many cases they are produced by software suppliers, but also third developers and users are now facilitate to arrange their ones.

The fundamental for any georeferenced place location is the coordinates. This set of x, y, z measurements allows for an unambiguous point in the space. After the aforementioned Meridian Convention of 1884, and the recognition one century later of the World Geodetic System (then revised in 2004)[19], longitude and latitude are highly accurate everywhere. The exact location is measured using GPS, and in future its European homologous, *Galileo*[20]. Instead, elevations (z coordinate) are still questionable, as almost each country (and some Agencies as well) has its own mark of the 'sea level'. Even though spatial analysis frequently regards flat surfaces, the complexity of the landform, and the use of under- and over-ground spaces must force analysts to adopt three-dimensional working environ-

[19] NGA, Geodesy and Geophysics Basic and Applied Research, http://www.unoosa.org/pdf/icg/2012/template/WGS_84.pdf

[20] European Communities No. 11 (2007), Co-operation Agreement On a Civil Global Navigation Satellite System (GNSS) between the European Community and its Member States and Ukraine, Crown Copyright 2007.

ments. Then, also the fourth dimension is crucial, in order to render in the most perfect way the dynamic nature of phenomena. For instance, the tube or a cable car would be not considered in a standard analysis: to be adequately evaluated they need all the four dimensions.

This dissertation is going to be investigating the totality of space, the totality of phenomena occurring within an evolving space-time. To be able to do so, this chapter is aimed to fix the basilar concepts of geospatial analysis and geostatistics, and provide useful information concerning geospatial processing programs.

Geospatial analysis is the process of display, and investigate through statistical analyses geographic data gathered onto a GIS software. It makes visible hidden information, providing detailed models and predictions. Born for epidemiological reasons[21], the many applications of spatial analysis currently range from military operations to climate change modelling, from risk management to population growth forecasting. GIS technology can interweave different kinds of data, creating a coherent datamodel from which decision-makers can determine appropriate answers to contemporary and future issues. Statistical analysis applied to geographic data, called *geostatistic*, provides methodologies to determine spatial correlations of entities and their locations, so that predicted values can be calculated. To establish the statistical relevance of investigations, the **interpolation** of points helps in identifying trajectories, rendering predicted values. Continuous data—i.e., data spaced-out with a certain interval of time—give a series of values that are converted into points. These form a region of space, which is turned into an area by GIS, through the process of interpolation. Some non-continuous data is considered in the same manner, as their trajectory can be evaluated.

***interpolation**, in the mathematical field of numerical analysis, is a method of constructing new data points within the range of a discrete set of known data points.*

Data are represented on telematic platforms capable to visually display spatial information. Through digital cartography, graphics can be realised directly on the map, or in parallel sheets that convey all the outcomes. One can create wall maps in which the results of simulations of potential phenomena are exhibited. Telematic maps have the great virtue of facilitate the share of information, and facilitate distribution, using web-based programs. Moreover, further analyses can raise from information sharing. While traditional maps have been portraying physical objects with points, lines, and solid and hatched patterns, through these and other symbols and techniques digital maps create correlations between physical entities.

[21] The first a nalogue geospatial analysis was made by the physician and epidemiologist John Snow in 1854, tracing the clusters of a cholera outbreak in Soho, London.

So, these can be extract, interpreted, and combined, creating always-new descriptions of the real world. For instance, height data can be combined with raster images, in order to render the image of a three-dimensional territory. As mentioned in chapter 2.2.1, data must be gathered without predetermined targets, whereas the analysis cannot be indiscriminate too. This starts trying to figure out what sort of information you need, ‘in the form of a question’ (Mitchell A., 1999) to the analytical tools, to become then more specific and focused on something one is being discovered. To be as specific as possible in the final questions means to obtain more accurate and significant statistical results regarding spatial phenomena.

Spatial features of entities are most often represented as points, lines, and surfaces. Points are defined by two or three coordinates, depending on whether the analysis is bi- or three-dimensional; lines—no matter if straight or curved—connect points, and define boundaries, or illustrate trajectories; surfaces define specific features contained within a boundary. Of course the complexity of information is richer in surfaces than points, but surfaces could not exist without point, whereas it is not true the opposite. Any entity one need to represent and study needs a GIS software equipped with specific analysis tools that are chosen depending on the scope of the research, and the purposes of the investigation. Even though the difference between academic platforms, and those managed by governmental Agencies cannot be neglected, the subjects of products, such as specific packages, satellite images systems, Earth modelling devices, are the same. There is a number of software and applications available on the market, both finalised to specific purposes, and specific ones. Originated to capture and study raster images data, rather than spatial analysis, soon the latter necessary followed the former.

Geographic features have precise attributes that characterise its spatio-temporal nature, and its level, or magnitude. Of course the typology of investigation strictly depends on the attributes available. They are divided into category, rank, count and amount, and ratio (Mitchell A., 2005). Categories divide data into group with same kind of values, or characteristics. Rank set entities in a logic order from the lowest to the highest, such as a territory subject to storms from the lower-risk area to the highest-risk one. (Ranks have adimensional values, so ratios cannot be derived directly.) Counts and amounts measure the quantity of an enquiry, and from these the ratio can be calculated, i.e. the relationship between two numeric values, determined as proportions or densities.

The understanding of data one is working with helps determine the method, the program, and the analytical tool alike. It also gives the suggestion of whether the amount of data collected are enough for a specific kind of analysis, and whether the quality of them allows for a statistically relevant outcome. Therefore, one can decide to widen the period or the area of the analysis, and then what information include on the chart, table, or map. The outcomes provide a clear vision of past, contemporary and future events, and once these are rendered they can be ascertain through further analysis, comparisons, and litmus tests. This process finally creates a series of information that are new input for other studies, for the principle of reuse of data (see Ch. 2.2.1).

Spatial questions and analyses through GIS can also answer more subjective questions responding to the combination of specific aspects of phenomena. Combining data, analysts have the chance to identify the best location regarding some parameters, to evaluate where a certain flow will likely go to, or which could be the most efficient path for a travel. These analyses are managed to endorse decisions, and form the very crucial point of the entire decision-making process. That is, while GIS cannot take any decision by itself, what is the role of the decision-maker, what is the role of the architect? Indeed, GIS is not able to decide and change criteria and parameters, because of its absence of willingness. As a matter of fact, it could even set a series of parameters, but it would not be able to select criteria. Telematic systems make every complex event easier to visualise and comprehend, but the consciousness is something innate in humans. So, let not computers take over human intelligence. The greatest benefit we can take from digital intelligence is its flexibility and adaptation capacity: there may always be another tool or datasets that could change the outcome. New criteria and future researches rapidly transform the most avant-garde model in something obsolete. The process stays, but any answer is never definitive.

The methods of spatial data analysis concern data *visualisation*, *exploration*, and *modelling* (Bailey T.C., Gatrell A.C., 1995). The visualisation of spatial data has the objective of identifying the randomness of a distribution of georeferenced entities, their homogeneity or heterogeneity, the presence of outliers, and anisotropic phenomena. Exploratory methods for spatial data provide precise data description, and the development of hypothesis and assumptions that are going to be tested using statistical models. Then, spatial phenomena modelling provides representations of spatial dependence between entities, and large scale and local trends. The dividing line between visualisation and exploration is made on the data manipulation: exploring spatial data means their manipulation. Four specific problem can raise in spatial data analysis (Barber G.M., 1988), as follows:

1. Edge of boundary effect
2. Scale problem
3. Spatial autocorrelation
4. Modifiable areal unit problem

1. The boundary effect occurs when entities' patterns change with the variation of shape and the arrangement of its boundaries.[22] So identical spatial data can be calculated as dispersed, and then clustered, depending on the domain of the boundary; 2. Patterns can be interpreted in different ways depending on the zoom on the area considered for the analysis: a random distribution could be read as a cluster on a different scale; 3. The interdependent variation of features within a territory causes a violation for some statistical tools based on observations' independence; 4. When data are collected into districts, any resulting value is subjected to changes, depending on the choice of the district.

The pattern analysis leads to a series of studies that measure the geographic distribution, allowing calculating the mean centre, directions and orientation, and to track changes in the distribution over time. The *mean centre* calculates the average x and y coordinates of all the entities of the study area[23], identifying the ones with the lowest total distance to all other features. The *standard deviational ellipse* represents a typical way to evaluate the trend of anisotropic geographic phenomena, calculating separately the standard orthogonal distances[24]. In so doing, the dispersion of points around the mean centre can be measured, define the axes of the distribution, where the major axis coincides with the direction of maximum spread.

The *nearest neighbour analysis (NNA)* measures the degree to which entities are distributed. Any distribution of spatial attributes within a specifically defined area creates a pattern helpful to understand phenomena, and track changes. These patterns can be *clustered*, *random*, or *dispersed*, depending on the relation between points, and the scale of analysis. Their

[22] BESR, 2002, *Community and Quality of Life: Data Needs for Informed Decision Making*, Board on Earth Sciences and Resources, Washington, DC.

[23] Mitchell A., 2005, *The ESRI Guide to GIS Analysis, Volume 2, Spatial Measurements and Statistics*, ESRI Press.

[24] Bishop M.A., 2007, 'Point pattern analysis of eruption points for the Mount Gambier volcanic sub-province: A quantitative geographical approach to the understanding of volcano distribution', in *Area*, Vol. 39 No. 2, pp. 230–241, Royal Geographical Society, The Institute of British Geographers.

measures across the study area, with the criterion of the 'nearest neighbour', highlight the degree of each condition. Generally, the average distance between entities in a clustered pattern is less than in a dispersed one, and the inter-point distance of a random pattern is larger than a clustered pattern, but smaller than a dispersed one. The ratio between the observed average distance and the expected average distance gives the *nearest-neighbour index (NNI)*, which ranges between two theoretical extremes, 0 and 2.149[25]. The closer NNI gets to 1, the more randomly spaced the data is. Thus, the closer NNI is to the extremes, the more uniformly spaced or clustered the points are.

Asserting that 'everything is related to everything else, but near things are more related than distant things', W. Tobler (1970) expressed the very nature of spatial autocorrelation. One of its oldest indicators is *Moran's I*, which compare the value of the variable of an entity with all the others at different locations. *Moran's I* identify whether patterns tend to be clustered, random distributed or dispersed, rather than their identifications themselves. This tool allows for the measure of similarity of neighbouring features, based on their location and values, and can also analyse the outliers. Then, the level of clustering can be evaluated via the *general G-statistic*. This measures the concentration of high and low values within a study area. It is useful to compare spatial patterns at different scales, in order to evaluate which type of cluster is better to take advantage of, depending on time and location.

The variety of tools shown above is going to be used in this dissertation (see Ch. 3.3.1) for the *cluster plan* of the case study in London. They allow for a detailed understanding of local dynamics, and helps in forecasting future trends. The program these investigations are carried on is *ArcMap*, the main component of *ESRI*'s *ArcGIS for Desktop*[26], a specific suite for geospatial processing. The information one creates on digital platform add value to one sector's knowledge, and shall transform how decisions are made and results are realised.

[25] Kang–Tsung C., 2008, *Introduction to Geographic Information Systems*, McGraw Hil, Boston.

[26] http://www.esri.com/software/arcgis/arcgis-for-desktop

NOTES

[6] The calculation of Earth's circumference is probably before Eratosthenes (276 - 194 B.C.). In fact, the buildings of some Egyptian temples may reproduce on scale the dimensions of some terrestrial features—for instance, the perimeter of the Pyramid of Cheops measures exactly 1/120 of the degree of the Egyptian meridian. It is likely to suppose that mathematicians and astronomers had calculated the value of Earth's circumference during the IV Dynasty, in the 26th century B.C.

[21] The mean center is the average x and y coordinate of all the features in the study area. It's useful for tracking changes in the distribution or for comparing the distributions of different types of features. The weithed mean centre is given as:

$$\bar{X}_w = \frac{\sum_{i=1}^{n} w_i X_i}{\sum_{i=1}^{n} w_i} \qquad \bar{Y}_w = \frac{\sum_{i=1}^{n} w_i Y_i}{\sum_{i=1}^{n} w_i}$$

[21] To measure the trend for a set of points or areas one can calculate the standard distance separately in the x and y directions. These two measures define the axes of an ellipse encompassing the distribution of features. The ellipse is referred to as the standard deviational ellipse, since the method calculates the standard deviation of the x coordinates and y coordinates from the mean center to define the axes of the ellipse. The ellipse allows you to see if the distribution of features is elongated and hence has a particular orientation.

$$\tan\theta = \frac{\left(\sum_{i=1}^{n} \tilde{x}_i^2 - \sum_{i=1}^{n} \tilde{y}_i^2\right) \pm \sqrt{\left(\sum_{i=1}^{n} \tilde{x}_i^2 - \sum_{i=1}^{n} \tilde{y}_i^2\right)^2 + 4\left(\sum_{i=1}^{n} \tilde{x}_i \tilde{y}_i\right)^2}}{2\sum_{i=1}^{n} \tilde{x}_i \tilde{y}_i}$$

[22] The nearest neighbour formula will produce a result between 0 and 2.15. The formula is as follows:

$$Rn = \frac{\bar{D}(Obs)}{0{\cdot}5\sqrt{\frac{a}{n}}}$$

Il terzo capitolo è il cuore della ricerca: i nuovi strumenti illustrati precedentemente sono applicati alla progettazione. La Sezione 3.1.1 analizza la relazione fra complessità, identità e resilienza, presentando il caso pilota della ricerca. Finalizzata a mettere in pratica gli studi spazio-temporali relativi ai big data, la Sezione 3.1.2 esamina l'uso in tempo reale della città. Successivamente, l'importanza della flessibilità nel progetto infrastrutturale è spiegata nella Sezione 3.2.1. La Sezione 3.2.2 presenta le linee guida che dovranno guidare nuovi interventi a scala territoriale, come rete di azioni. La Telematic Map of Risk è introdotta nella Sezione 3.3.1. Si tratta di una piattaforma per la pianificazione che consente il governo della città lavorando in maniera anticipatoria considerando eventi futuri previsti. Infine, la Sezione 3.3.2 esamina come questa innovativa piattaforma è in grado di ridurre il livello di rischio locale relativo alle esondazioni.

This third chapter is the core of the research: the new tools illustrated in the previous chapter are applied to the design process. Section 3.1.1 analyse the relationship between complexity, identity and resiliency, and present the pilot case of the research. Aimed to put into practice the space-time studies related to big data, Section 3.1.2 examines the real-time use of the city. Then, the importance of flexibility in infra-structural design is explained in Section 3.2.1. Section 3.2.2 presents the guidelines that shall drive new developments on the territorial scale, as network of interventions. The *Telematic Map of Risk* is introduced in Section 3.3.1 as a new planning dashboard capable to govern the city working in anticipation on future predicted events. In the end, the way this new platform is going to lower the local level of flood risk is examined in Section 3.3.2.

3 DYNAMIC MAP FOR RESILIENT CITIES

Open source city

The complexity of cities 3.1.1

> "Complex systems such as the climate, economic systems, organisms, populations, markets, or communication networks cannot be guided like mechanical devices. But they do obey nonlinear laws of self-organization that are thoroughly amenable to human understanding. [...] But we can simulate their dynamics on computers, thereby investigating typical patterns of behavior of the total system under the relevant auxiliary condition."[1]

Cities—architecture made material—are the most complex realities one could imagine: they are multi-layered organised systems of complex organisms forming the ecosystem, which is part of a global complex structure contained within the atmosphere. To this complexity *per se*, another aspect of complexity is added by humans' perception, as architecture is visual experience, use of space, and spatial experience. Cities, i.e. architecture, need a special care though, as one could avoid being interested in maths, philosophy, or history, but s/he cannot avoid the experience of the built environment. We all are immersed into architecture, and we are part of our cities, whether we like it or not. Thus, the core is the relationship of the part and the whole: people and their houses, buildings and their blocks, blocks and their boroughs, and so forth. These relationships point out that

[1] Gleiniger A., Vrachliotis G. (eds.), 2008, *Complexity. Design Strategy and World View*, Birkhäuser Verlag AG, Berlin, pp. 90-91.

planning processes must not be objectified, and that the Modernist value of reducing complexity of space to functions in relation to the structure cannot be the one-off criterion. Moreover, the standardisation of development processes raises the decontestualisation of architecture, which lead to loss of identity (see *genius loci*, Ch. 2.3.2).

The simplicity of first forms of societies and communities had been made more complex by the addition of other layers, which might be simple by nature, but can result in the development of a complicated system. While a complicated system must be avoided, the level of complexity that cities have reached can be lowered not just weeding out toxic elements, but trying to condense all the information onto an infrastructure able to give a simultaneous understanding of phenomena. Usually, infrastructures facilitates in connecting two conditions contrasting by quality, distance or level. Commonly considered as a physical connection, in the last decades the meaning is slightly changed. Through the introduction of the so-called immaterial technologies in our daily lives, the exchange of virtual data has been facilitating connections between users—and between users and systems—, accelerating social dynamics, information exchanges, and making data sharing more democratic. In considering those kinds of drifts, we can talk about acceleration regarding demographic growth, urban development and data sharing. The community as a whole shall take advantage of the relationship between these progressively increasing aspects of urban planning management.

Through the connection of societal accelerations, the very meaning of complexity can be understood. Big datasets are nowadays the only way to understand complex phenomena and link them, so that the physical reality is analysed connecting all its manifestations. As cities become more complex, their flexibility drastically decrease, because of the number of components under risk. **Resilience** is the anticipatory capacity of dynamic processes to adapt to significant threats. It is defined by the *European Climate Adaptation Platform* (Climate-ADAPT) as '[t]he ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change'[2]. The very intrinsic nature of resilience is the dichotomy of two conditions: exposure to hazards, and the achievement of stability—which does not necessarily mean the return to the *status quo*. The exposure to catastrophic phenomena is a circumstance that cannot be avoided, even though their magnitude may be lowered in

***resilience**, in material science, is the ability of a material to absorb energy when it is deformed elastically, and release that energy upon unloading.*

2 http://climate-adapt.eea.europa.eu/glossary#linkResilience

future through mitigation at global scale. On the other hand, efforts for a stable condition regarding all the adaptive processes at the local scale plays a crucial role. Thus, mitigation and adaptation as two sides of the same coin coincides with the tension between exposure and achievement of stability.

The limits of developing strategies for disaster resilient communities rest at two different levels. The first one regards the infrastructures of cities. In fact, their complex nature makes the coordination of many systems, Agencies and organisation quite difficult to be transformed and updated over time. Moreover, the increasing extension of metropolitan areas limit the control over any system by a single Region, decreasing the local capacity of implementing and integrating infrastructures (no matter whether physical or digital.) The second barrier is ideological: the vast majority of Governments, even welcoming mitigation and adaptation frameworks, do not take long-term measures to reduce communities' exposures. Scepticism about the effects of global warming on the environment annihilates any pragmatic agenda and plan.

Focusing on environmental sustainability, the binomial pair 'decision-taking' and 'action-making' highlights the necessity to centre new developments on disaster risk management. I.e., the entire decisional process "has to shift from shielding social and economic development against what are seen as external events and shocks, to one of transforming development to manage risks, sustainably seize opportunities, strengthen resilience, thereby ensuring a sustainable development." (UNISDR, 2014) We are facing, thus, a strategic phase characterised by the switch from a defensive strategy to a collaborative one. As a matter of course, the binomial must be converted into a 'decision-making' process, which means that decisions and actions are inevitable consequences one of the other, and cannot be sundered anymore.

Cities' dynamics, connected to the constant change of building stock, allow for innovative networking strategic developments aimed to treat the space as a public domain, rather than the sum of private ones. Regeneration strategies provide large varieties of activities tied to urban life cycles. These models are not just environmentally sustainable, but also economically advantageous over a long-term period. Through open data sources and social media, public involvement is nowadays easier than just a decade ago, and new data processing models can be developed. Today, the entire society, as a system, is extremely 'sensitive to the slightest alteration of its initial state' (K.Mainzer, 2008) and to any minuscule technological shift. GPS and GIS devices and tools shall drive decision-making process toward a direct feedback—a sort of real-time telematic dialogue—between people and urban planners. This loop feedback allows for a new flexible design, in which sustainable frameworks become plans of systematic interventions that link social issues to economical feasibility. Thus, it is clear that the very nature of sustainability regards the whole decision-making process, and the use of resources is naturally the core of its system. The first resources playing a crucial role lay at the ground of it: all the digital datasets, Agencies' dashboards, GIS platforms, and people working on these networks are involved in shaping information and rendering the complexity of the city. For the purpose of ensuring coherent strategic planning, the wide understanding of sites is crucial.

The methodology adopted in this research works from the particular to the universal, and then back to the particular again. The change of scale is indeed necessary to understand the dynamism of phenomena, and to form coherent strategies that connect development sites to the territory.

After having studied the main policies the area is subjected to, such as PPS25 and TE2100, the first step begins with studying particular cases (the study cases, to which the SWOT analyses were elaborated), in order to understand the very nature of the relationship between man and water over time. These are compared to a specific site (the pilot case), so that the abstraction coming from the overall SWOT analysis (see Fig. 2.2) can be grounded onto an area that is going to radically change in the near future. Then, two master plans are developed for this pilot site: the first one comes from the traditional analysis of the area (master plan I), while the second one comes from the use of the innovative platform this dissertation introduces (master plan II). The aim of this process is to test the two different approaches to new developments. Indeed, it is crucial to understand whether the differences between the two would be substantial or not, and what the nature of these differences is.

Planning for the long term means to create a flexible urban system that is going to keep performing and affecting the future generations of the 22nd century. Flood risk management global strategies are developed by the Environment Agency until 2170.[3] The flexible response to change finds in the TE2100 Plan a number of key points that need to be connected to practical actions. For this reason, this dissertation proposes a methodology based on city layers consciousness aimed to produce guidelines to build the city of tomorrow. Maps, simulations, and data provided by

[3] Environment Agency, 2012, *Thames Estuary 2100 Plan, Managing flood risk through London and the Thames estuary*, Environment Agency Copyright, London, p. 38.

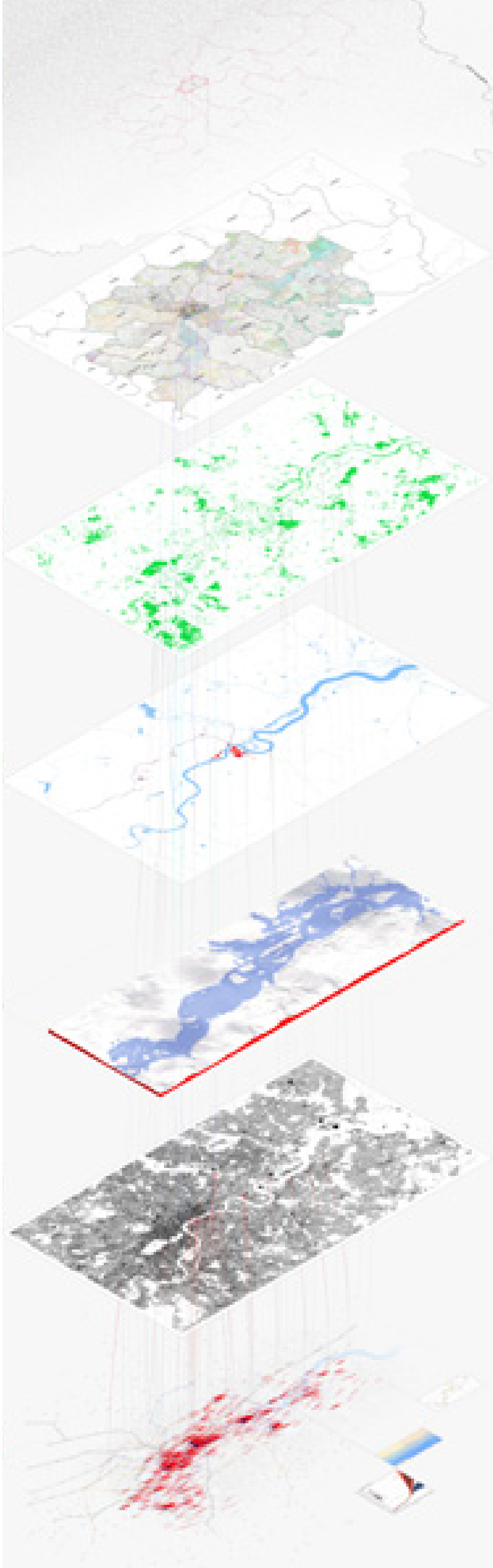


Plate. 3.1
Seven layers for the city.

Local Authorities and other stakeholders involved in the urban design process originate certain information. Thus, the whole city is used as an alive source of information. These are collected on a GIS-based platform from which it is possible to extract datasets for each area where a new development, or a brownfield intervention, or a consolidation on the firm built environment, is supposed to be done. In so doing we ground the logic of a comparative mechanism between areas with similar features and common level of risk that allows pilot cases to become a net of good practice widespread all along floodplains.

Hence, the level of risk for any area is evaluated through seven layers (Plate 3.1) that determine the city and contribute to its evolution over time.

(a) *policies:* top-down decisional process
(b) *plans:* boroughs' proposals
(c) *natural environment:* green and unbuilt areas
(d) *water paths:* seas, rivers, lakes, and canals[4]
(e) *landform:* flood (hazards) simulation
(f) *built environment:* over- and underground
(g) *real-time data collection:* bottom-up process

Policies and plans provide information about development strategies and future scenarios for natural and the built environment. The ones defined as 'simulation layers' ((c) to (f)) concern topographical and geological information, river morphology, existing and future infrastructures and structures, and the built environment information. (For the case study, these data are mainly extracted from *Edina Digimap*.) The bottom-up data give information about real-time and historic data. More in depth, this collection process—that is a tool and not the end product—is aimed at gathering information about operative norms (a); current and future planning interventions (b); green areas' density and typologies (c); water path depth, width, length and variations (d); features of riverbed (d); landform variations and kind of soil (e); flood simulations (d, e); building density, typologies, dimensions and state (f); typology of embankments/flood-defence-systems (f); infrastructures typology, extension and relationship with urban structure (f); population density and movements (b, g); water levels and meteorological information (g); existing preparedness systems

[4] Canals are mapped both in current and historic paths. The Town Plan maps are available on *Edina, Digimap* for 1:500, 1:528 and 1:1056 scales as the original sheets and as National Grid tiles, both in TIFF format. These maps were produced between the 1840s and the 1930s in a first edition and up to three revisions. (http://digimap.edina.ac.uk/digimap/home)

and other demographic information (g); people's location and information feedbacks (g).

These seven entities, each one characterised by socio-political and spatio-temporal features, are the evident proof of the complexity of a system. Indeed, their boundaries are defined by structural differentiations, yet at the same time they are part of a unique organisation that goes by the name of «territory». Mapping the territory and collapse all the data gathered onto a single platform means a rapid and substantial loss of complexity. We can assert that, in some ways, complexity was born to solve problems (J.A.Tainter, 1988); in fact, when a certain level of congestion or over-complexity is reached, it is necessary to re-organise the entire logic of one system.

So far, traditional top-down approaches to design complex systems are the consolidated way to adopt measures aimed to modify public and private space. To better understand how to reduce information complexity, a first mapping is developed as a case study, on the areas ranging from Fulham to Woolwich, focusing on flooding. As GIS-based map, it shall be considered as a multi-hazard tool aimed to form and support decision-making processes of **LPA**, the *Local Planning Authorities*, to foster disaster resilient societies.

***LPA** is the local authority or council that is empowered by law to exercise statutory town planning functions for a particular area of the United Kingdom.*

Within the simulation layers, great importance is given to the dynamics of water, and paths and courses' changes. In terms of natural course's variation, the River Thames has undergone very few changes if compared to the studies on the River Mississippi by Harold Fisk[5]. Nevertheless its banks have been changing more than expected over the last centuries, mainly through anthropogenic works. River Thames wise, from the comparison of Figure 2.8 and current maps, it is easy to point out the alterations of docks' areas. (See West India Docks, Wapping's London Docks, Blackwell's East India Docks, Rotherhithe's Surrey Docks, and the Isle of Dogs.) A change in the use of a river can indeed drastically varies landform, canals, and shipyard basins. Moreover even inner canals change their paths mainly due to new developments and infrastructures, such as railways and roads.

The other aspect that relates water paths (d) and the landform (e) is the prediction of water dynamics over a one hundred year time. Landform surface is extracted from the tiles that connect each section of London

[5] In 1941 the *Mississippi River Commission* appointed Harold Fisk to undertake a geological survey of the Lower Mississippi Valley. The *Geological Investigation of the Alluvial Valley of the Lower Mississippi River* (1944) is archived at the US Army Corps of Engineers, http://lmvmapping.erdc.usace.army.mil/

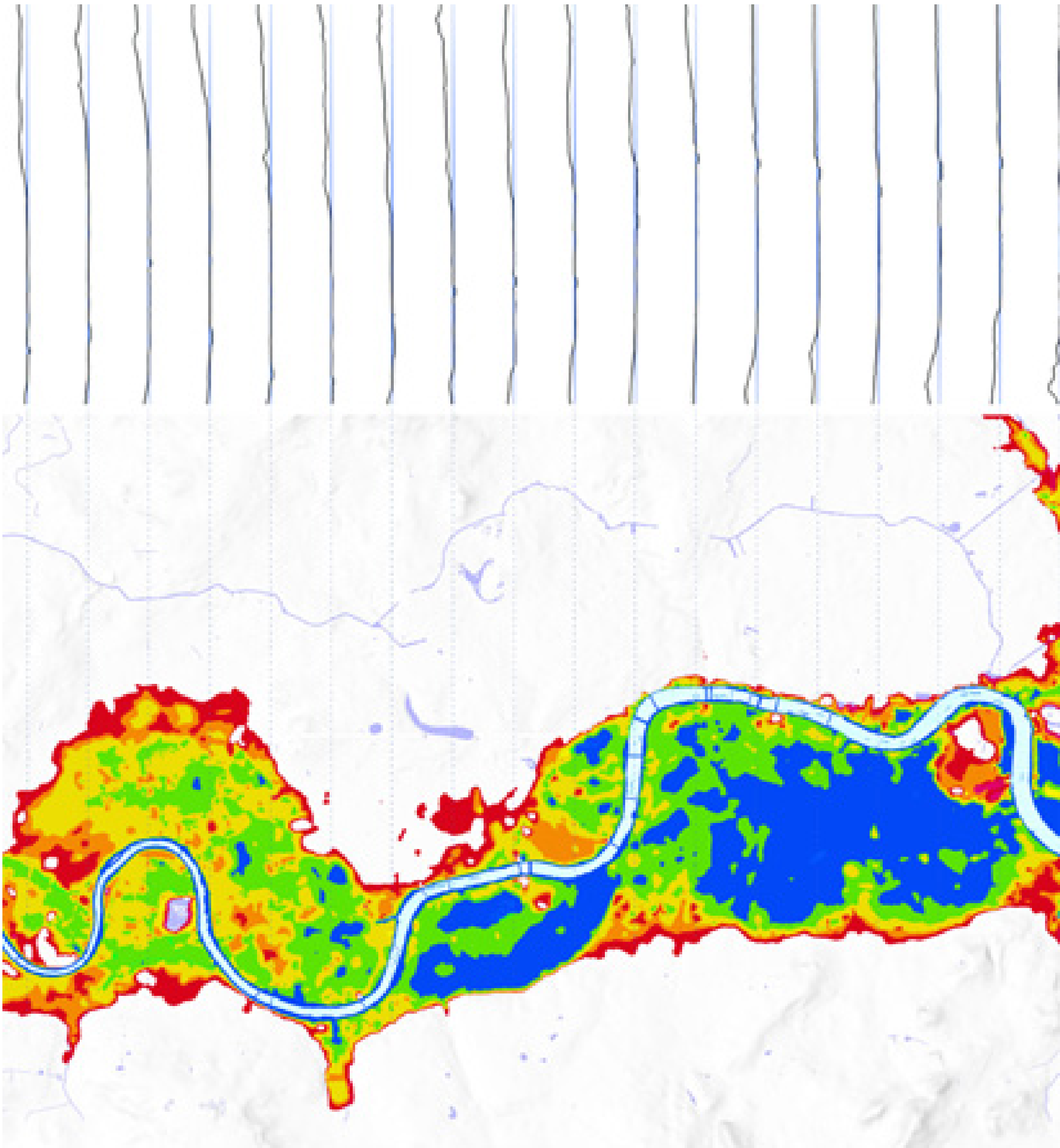
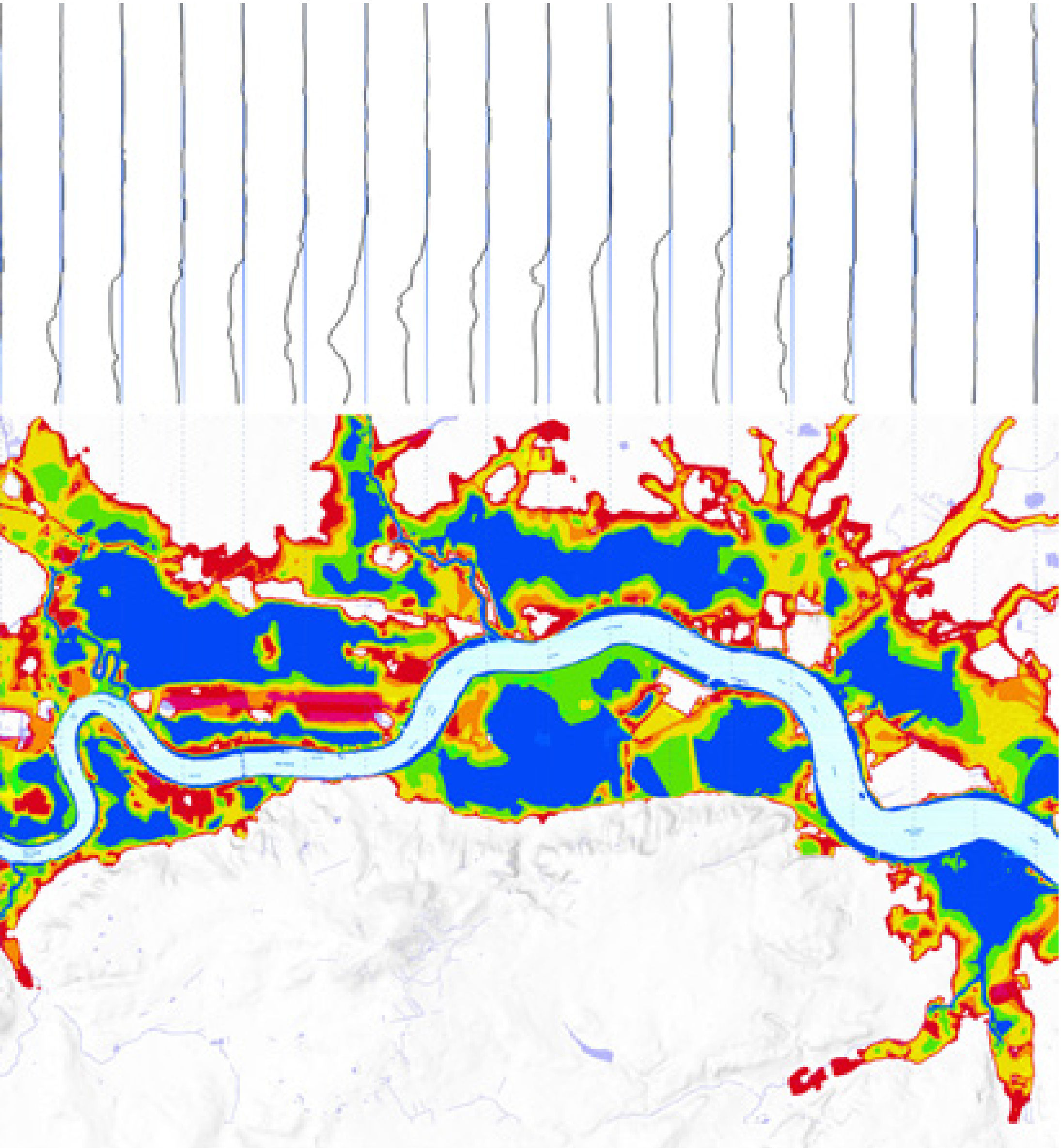


Plate 3.2
Levels of flood risk in London, between Chiswick and Dartford



Thames path
100 cm lower
50 cm lower
+ **84 cm** *flood level 0: Barrier failure
50 cm higher
100 cm higher

from *Edina Digimap*[6] as **shapefile** (.shp, .shx, .dbf)[7]. A square of thousands points with different heights evenly spaced is given; and the connection of these allows for the creation of the desired surface. As soon as the entire area of study is covered (35 km, 21.75 miles, in our case), one can understand tidal, river, and groundwater flooding phenomena simulating water flow. Rising the level of tide, it is indeed possible to define water within precise areas for any stage, and consequentially determine the level of risk (Table 3.2). From the level «0», which is the surge of water in case of Thames Barrier failure (+84 cm, 2.76 ft,[8] from the current highest level ever recorded—50 cm for the Environment Agency[9]), other four steps are outlined: -100 cm (-3.28 ft), -50 cm (-1.64 ft), +50 cm (+1.64 ft), +100 cm (+3.28 ft). So, these five levels of risk (hereafter we will be referred to as 'R1', 'R2', 'R3', 'R4', 'R5', from the lower to the higher) coincide with the Flood Warning and Alert Areas (**FWAA**), described by the Environment Agency, over the next one hundred and fifty years (see 'Recent projections of future sea level rise', 2009 UNSW Climate Change Research Centre, Fig. 1.8).

shapefile *format is a type of geospatial vector data format for GIS software, which describe spatial features: points, lines, and polygons.*

FWAA *services for areas at risk of flooding from rivers or the sea are are preventive warnings provided by the Environment Agency (EA) for England, Natural Resources Wales (NRW) and the Scottish Environment Protection Agency (SEPA).*

These water studies allow for the identification of the most critical areas at risk of flood. Moreover, the SWOT analyses (Ch. 2.1.1) led to a higher awareness of the socio-cultural issues that the master plan, on a large scale, must take into account. The industrial region in the London Boroughs of Newham and Tower Hamlets, right next to London City Airport, is chosen as pilot case, because it instantiate the centrality of all the arguments regarding political resilience, capital manipulation, and human resilience. In fact, the aim is to link urban analyses and the design process through a systematic morphological variation of the urban and natural environment.

The area is characterised by a strong separation in land use, since industries and varied infrastructures are dividing two densely populated neighbourhoods. Orography and river stream are the other main features of the site, with sudden speed variations of the Thames and the Lee. The area is considered at-flood-risk, and it needs to undergo deep changes. Through ground shape variations and canal paths alterations the goal is to allow some lands to be flooded and preserve other areas. At the same time, strengthening industrial embankments and compacting the residential use

6 http://digimap.edina.ac.uk/

7 Environmental Systems Research Institute, 1998, *ESRI Shapefile Technical Description,* ESRI.

8 http://www.theguardian.com/environment/2013/may/14/floods-thames-barrier-sea-level

9 The Environment Agency predict an even more dramatic scenario: the existing system should be able to withstand around 0.5 metres of sea level rise, according to the Environment Agency's report.

along the river, a new relationship with water is formed. The Thames and the Lee become again the real infrastructure to be used. The aim is thus to take advantage of the structure of the city in order to give new importance to the infrastructure: allowing water to become part of the urban fabric, a relationship between the natural and built environment that will be complementary.

Accurate series of studies of the industrial site between the Olympic Village and the Thames Barrier Park is conducted. The land use analysis (Plate 3.3) points out the complexity of the area, characterised by a dense melting pot of residential areas, service facilities, and industrial plants. Railways, the DLR, and motorways define smaller areas that assume the characteristic features of macrostructures. For each one of these, their functional mix and compactness is evaluated in comparison with the adjacent one, in order to understand the real weight of the cuts provoked by the infrastructures.

***Q** is the total volume of fluid that moves within a given surface per unit time. The SI unit is m^3/s and the Imperial unit is ft^3/s.*

A second study regards the ways to affect volumetric flow rate (**Q**) of watercourses, so that the level of risk due to the stream itself can be lowered (Plate 3.4). Three are the main strategies: new watercourses and paths, landform variations, and structural reinforcements. The creation of new canals and basins allows for the formation of controlled water expansion areas, and useful navigable connections with the built environment. Through ground morphology alteration we can take actions either to deepen watercourses for decreasing water velocity, or to lower or lift ground in order to allow or avoid water to make contact with objects. Strengthening embankments, dikes and levees can finally improve water controls both tin advance of the built environment, and the watercourse itself. As an example, these criteria are applied to the critical area where the River Lee joins the Thames. The studies on *RealFlow (Next Limit Technologies)*[10] demonstrate indeed that the actions described above do provide substantial improvements in water dynamics, as they are applied to a real case i.e., the pilot case.

Then, the sprawl of industrial sites over the territory, and the consciousness they are going to change quite rapidly over the next decades (due to typological metamorphoses) has brought the necessity of an in-depth analysis of this category (Plate 3.5). The industrial plants can be divided into three main categories: factories, stock and sorting depots, and

[10] *RealFlow* is a fluid and dynamics simulation tool for the 3D and visual effects industry, developed by Next Limit Technologies in Madrid, Spain. This stand-alone application can be used in conjunction with other 3D programs to simulate fluids, water surfaces, fluid-solid interactions, rigid bodies, soft bodies and meshes.

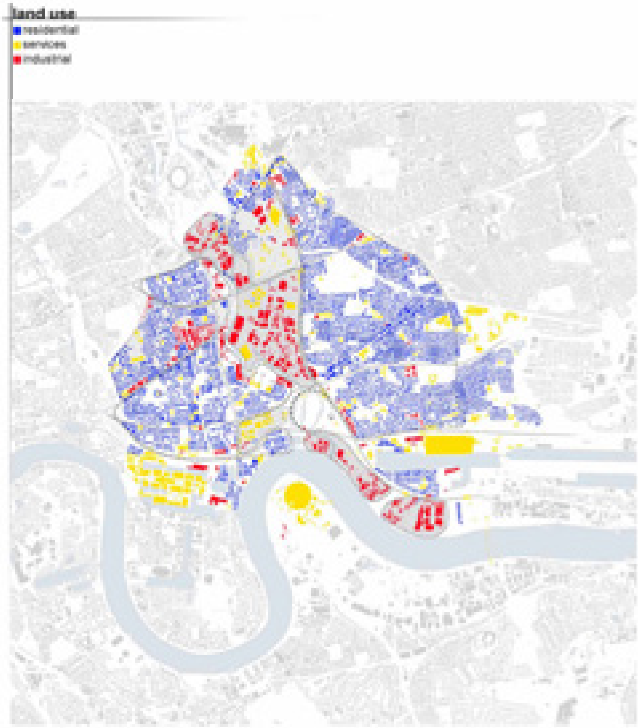


Plate. 3.3
Land use and river strategies.


macrostructures
compact residential
functional mix
compact industrial


residential structure
residential
infrastructural boundary
porous boundary

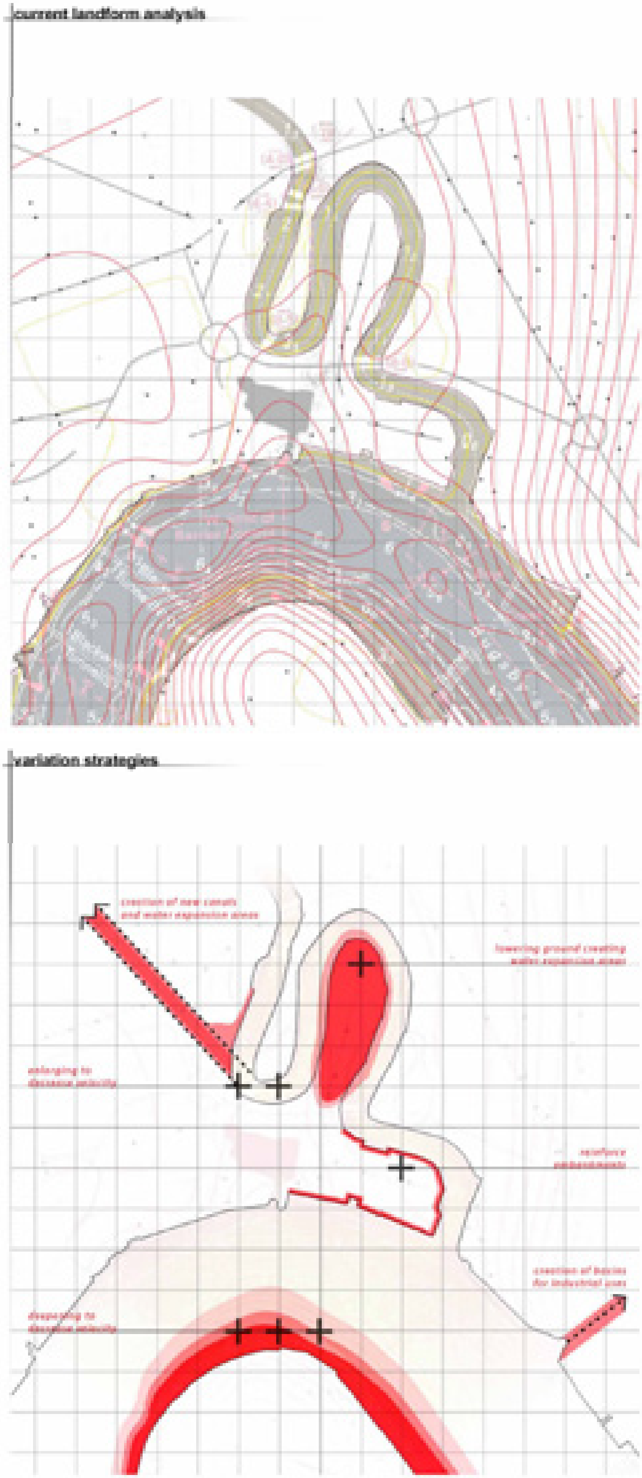
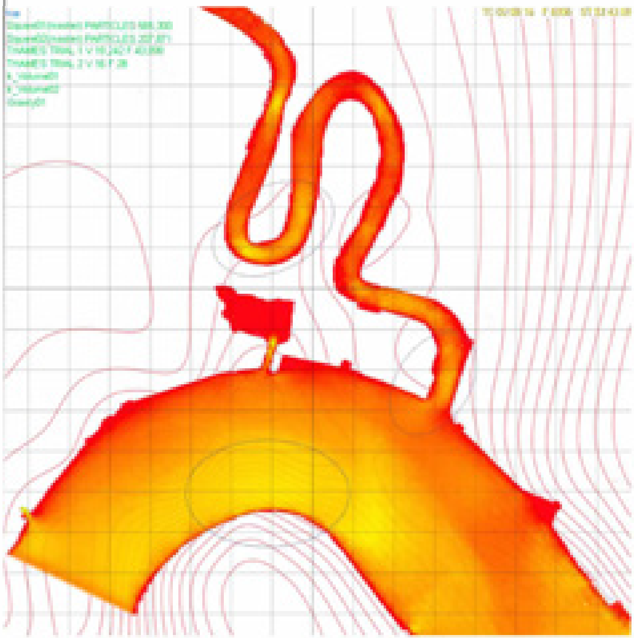


Plate. 3.4
Stream analysis and alterations.

current volumetric flow rate

highest volumetric flow rate (120m³/sec)

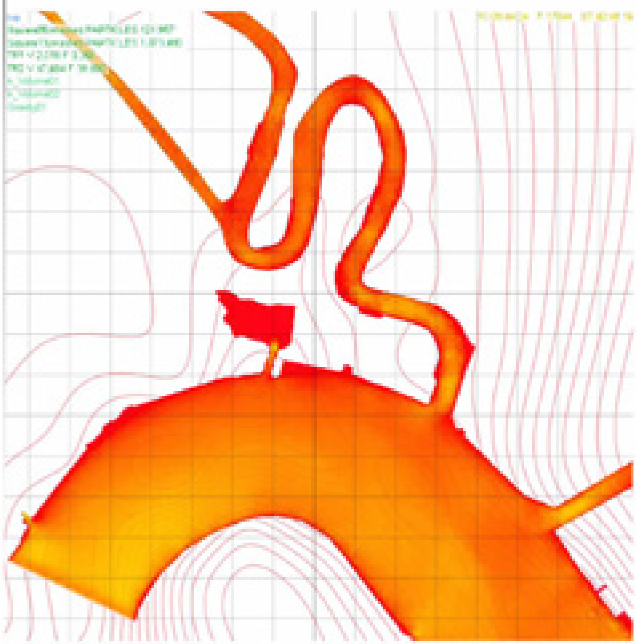
lowest volumetric flow rate (28m³/sec)



effects on the volumetric flow rate

highest volumetric flow rate (120m³/sec)

lowest volumetric flow rate (28m³/sec)



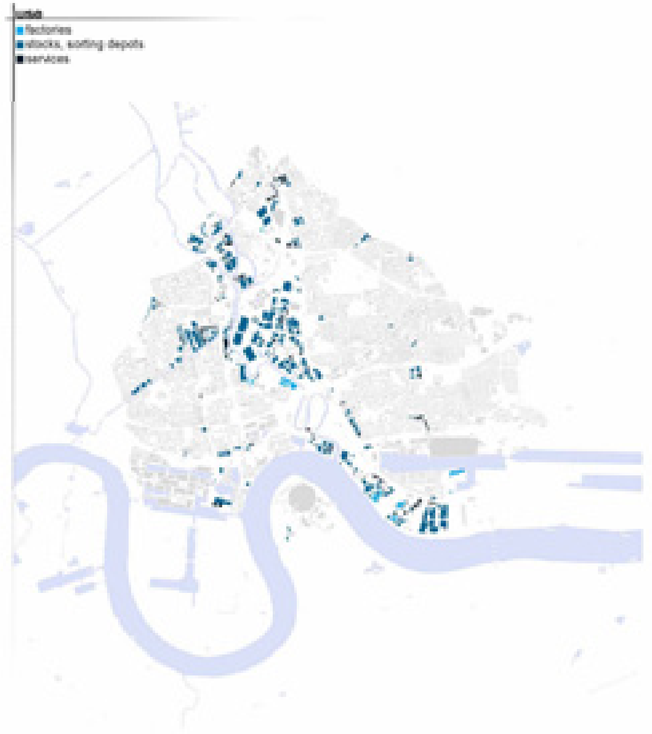
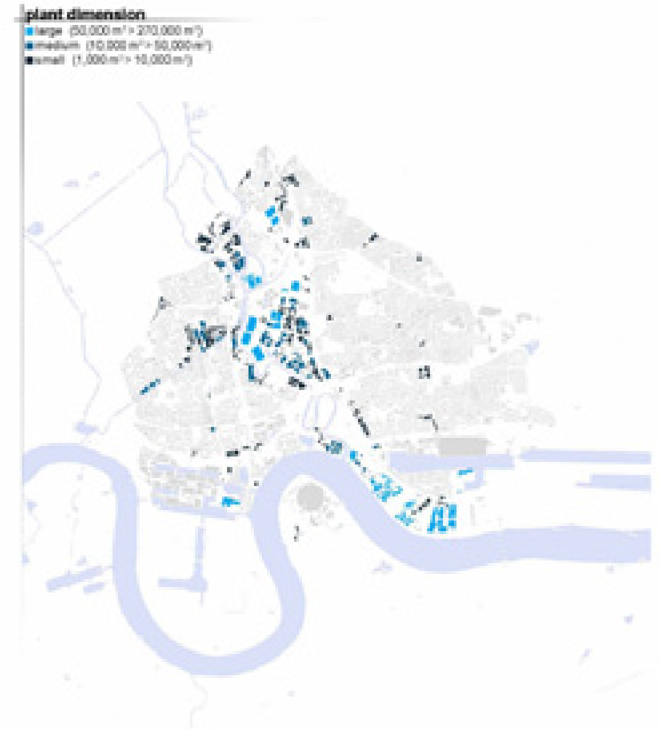


Plate. 3.5
Industrial sites analysis.


plant dimension
large (50,000 m² > 270,000 m²)
medium (10,000 m² > 50,000 m²)
small (1,000 m² > 10,000 m²)


state
abandoned
critical condition
in use

services. Factories are a minority compared to the depots, and are mostly facing the Thames River, besides being the most historic-architecturally relevant. Even though a number is still in use—just few of them are in critical condition or abandoned—a re-examination of urban perspectives is needed, in order to guarantee flexibility and replaceability in future. The dimensional analysis, which refers to the entire industries and not to the individual buildings, shows that the main ones are along the Thames and in the mid of the study area, while the smaller ones are spread over the whole site.

The criteria identified for the flexible substitution of industrial plants determine the sequence of interventions (Plate 3.6). This is meant to bring together the researches from the various fields discussed so far, and predict scenarios of change based on the infra-structural flexibility of the entire development. The first stage of the master plan (I) is logically the intervention on brownfield areas and disused sites—which are not concentrated within a specific area—, both for industrial and residential uses. The following step affects small plants and the disconnected industrial sites, as they can be moved to the areas developed by the first step. Then, the third one takes into account the biggest sites, which are going to be positioned in strategic locations, considering their transportation systems. The flexibility of the scheme pledges the variation in dimensions and uses over time, as the development grid is not a rigid one. Moreover, it does not create discontinuity with the existing urban fabric neither during the substitution phase nor when the system is already set up.

This infra-structural system demands for new different technologies. The contact with water also requires vertical flexibility, in order to cope with tides and flows (Ch. 3.2.1). All the interventions are focused on the relationship between the natural and the built environment. New canals and basins need to be designed for water control. The first ones allow for a water volumetric flow rate alteration, varying routes, width and depths. It is also possible to differentiate boundary features to control water levels and define areas designed to absorb floods. The second ones absorb water tides and directly connect industrial docks to industrial sites. Besides, platforms and floating areas can be created for fishing and leisure activities. Landform variations apply both to industrial sites and residential areas. The soil dug from canals and rivers to lower the riverbed, or to create new paths, is used to heighten the level of settlements, and industries and stocks can be placed on different levels, depending on their needs.

Industries built on pilework are designed to be connected to water paths both through ramps and cantilevered docks, depending on the level of the tide, and basements designed to be flooded preserve other parts of buildings and store water. Moreover, slopes, green areas and new streets control water expansion themselves, as they form the in-between areas. Floating houses, cultural and leisure centres within basins or rivers foster the active use of water path, and new technological devices can be used. For instance, flat and green rooftops accumulate and store water, and improve drainage and absorption systems that otherwise would have poured into the street level.

All these measures are decided depending on different levels of risk, which, after having been set, improve the local level of risk that determined themselves. To lower the risk through varied and individual different interventions is a structural operation on the built environment more than just an acupunctural process to improve the most risky realities. In fact, local interventions are the base for a diffuse common vision to cope with hazards throughout the floodplain.

The master plan (I) is developed in the respect of present needs, yet with a high degree of possible variations depending on future demands (Plate 3.7). The first sector is based on a radial scheme that follows River Thames' banks. It is characterised by a wide range of industries and stocks that complete the jigsaw puzzle, overlaying to the valuable ones that shall not be replaced, which are identified in the industrial site analysis. These form a gradient towards the under-construction housing and retail blocks next to the Thames Barrier Park (south-east in the master plan.) The gradual transition works through the use of craft activities, which realise the change of scale from industries to dwellings. Then, the northern part of the site consists of housing (sector 2), and industries (sector 3). The dwellings on the island-riverside park dialogues with the existing buildings, and are built on a plinth obtained using the ground excavated to build canals and basins or to alter the riverbed. Factories facing the River Lee are settled in order to create a series of basins for ship docking, while the smaller industries of the northern area are well connected to both the railway and the highway.

In considering the residential and industrial areas, the logic of typological continuity has been harmonised with the flexibility that new relationships with water paths and green areas require. When physically interrupted by the Lee River or by one of the new canals, the continuity of space is entrusted to the visual field. The greatest lesson on continuity

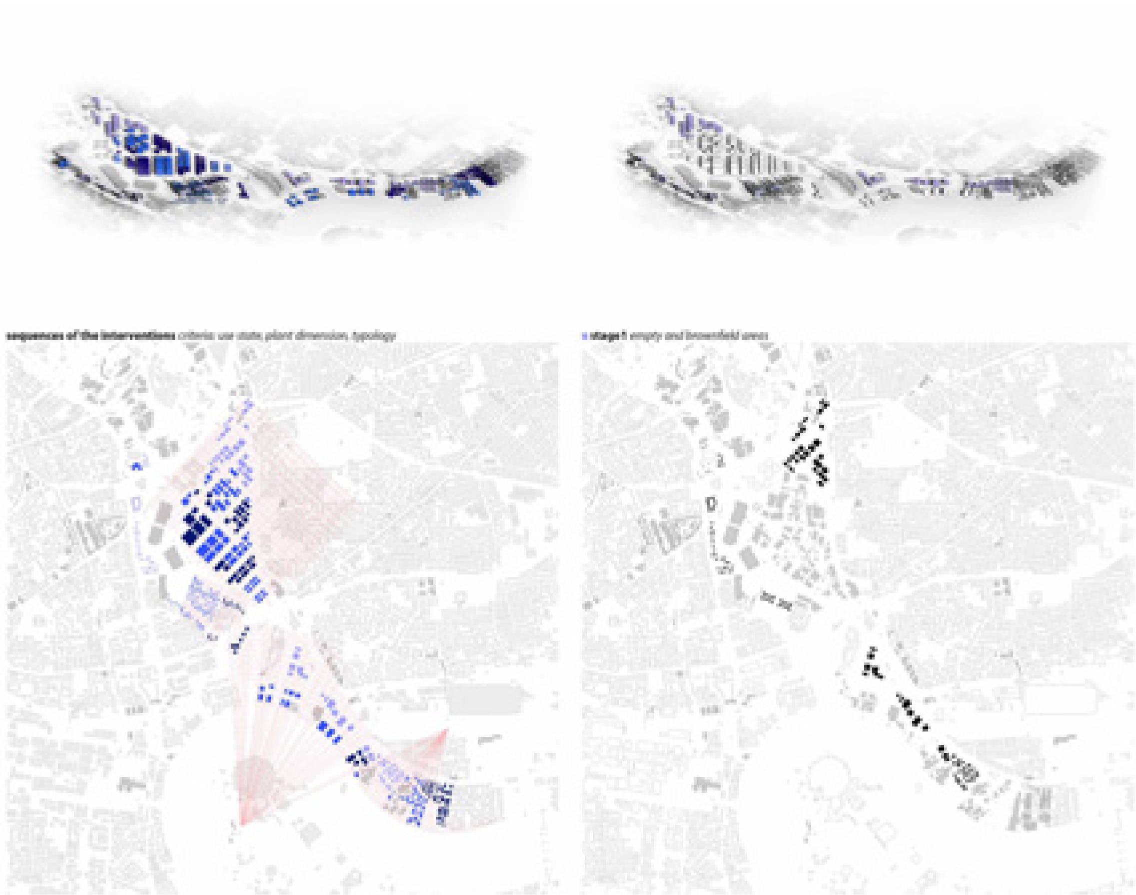
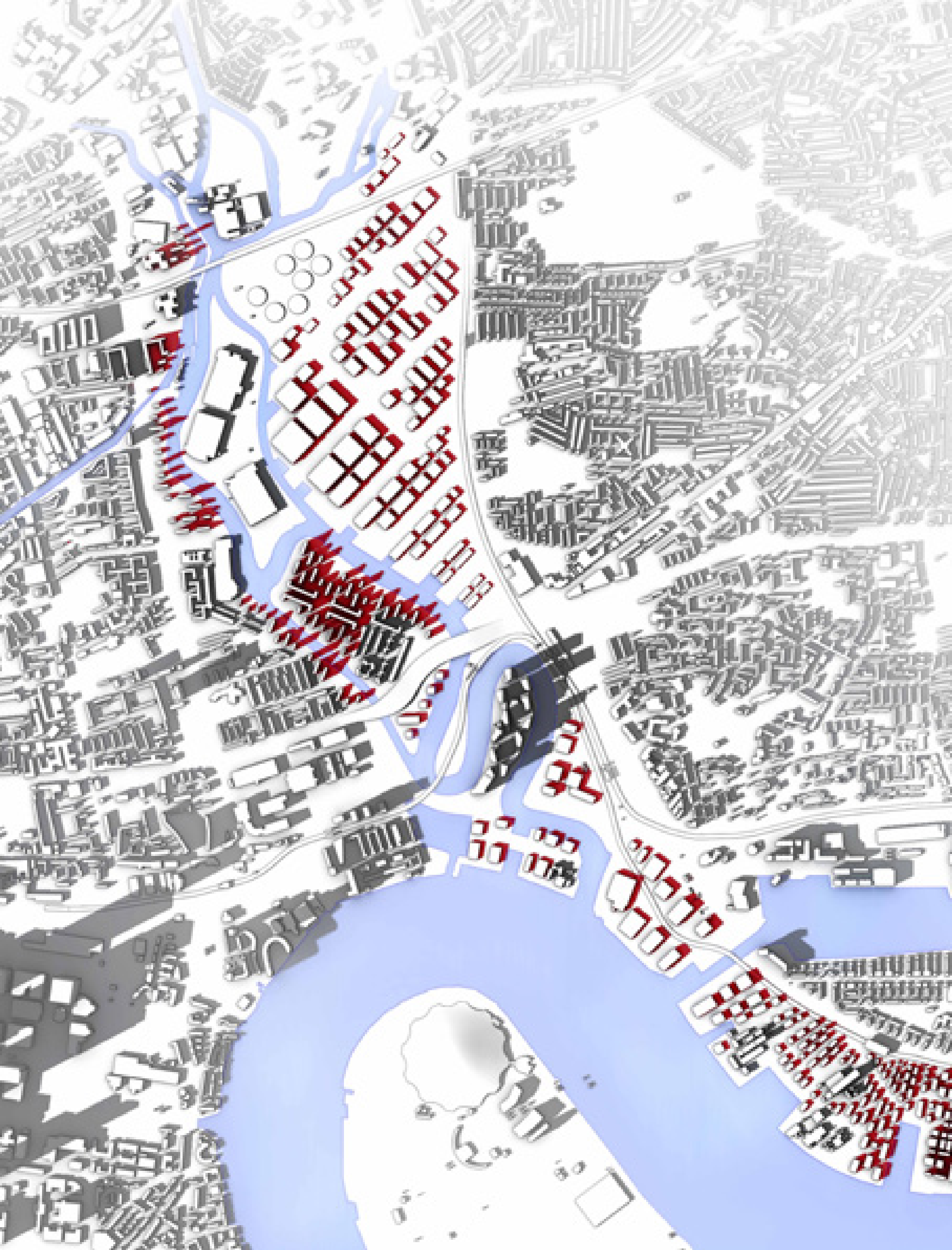
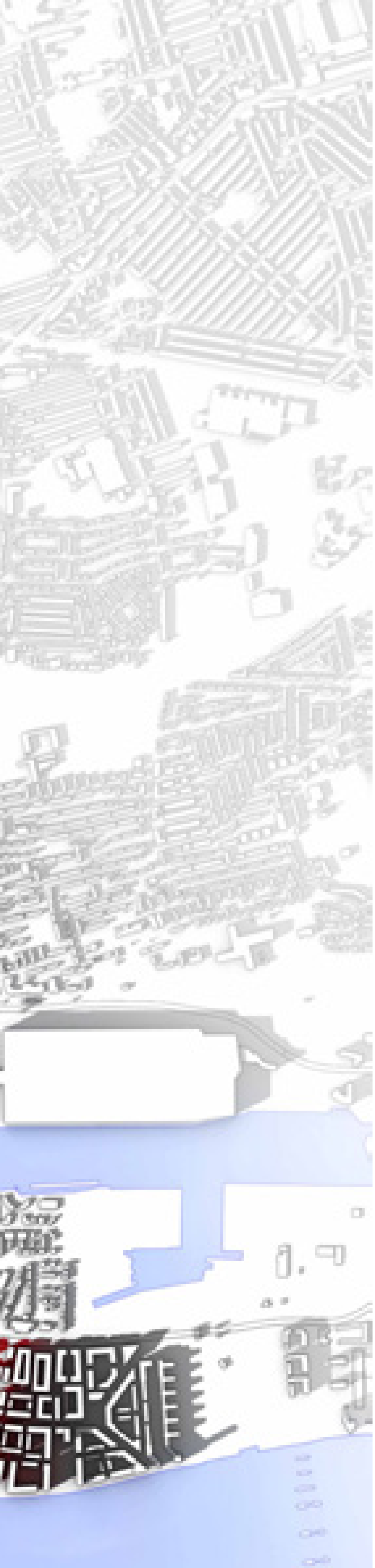


Plate. 3.6
Sequence of interventions.

stage2 *substitution of small and disconnected industrial sites*

stage3 *substitution of biggest sites*





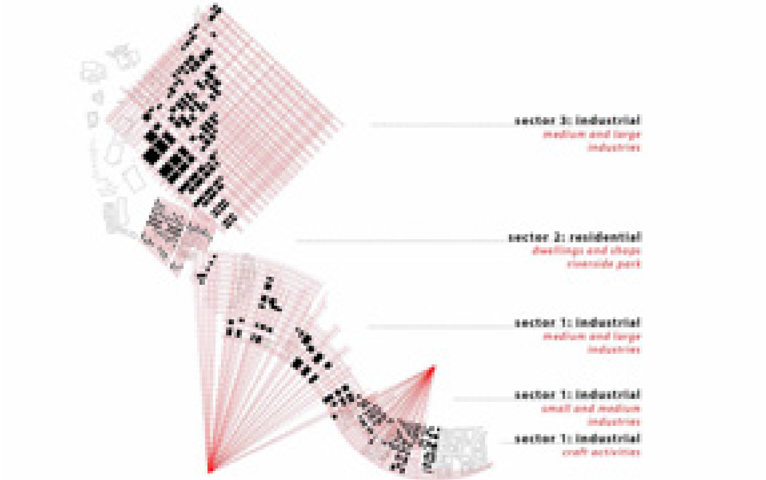


Plate. 3.7
Master plan (I).

of variation was given by G.B. Piranesi in the *Campo Marzio*[11] etchings (1762), a provocative experimentation aimed to destroy the type through the exaltation of the type itself. In the plan (Fig. 3.1) and view he hatched, the river assumes a fundamental role of physical disconnection to highlight the typological continuity. Moreover, the infrastructural strength of the Tiber is enhanced by a number of Roman architectures that are directly connected to water, demonstrating the importance of the river use for human activities. Piranesi's *Campo Marzio* is one of the rare metaphorical representations of the city (a notorious precedent is *The Ideal City* dated late 15th century.) The aggregation of buildings—that are all masterpieces of architecture—is not structured on any logical order: each single building is an exceptional event disconnected to the adjacent one. The city is not designed organically anymore: through the exaltation of the *archetypon*, Piranesi destroys the *typos*. Yet, reversing any rational thought, he decides to connect what is physically distant. That is, he visually and typologically relate buildings on the two banks of the Tiber. This is his great revolution. Infrastructures are not just voids between blocks, but the connective fabric that position each building onto a common ground.

The master plan (I) proposed is indeed based on these principles, as it considers infrastructures as complementary entities for the city as a whole, and its structural elements as the fabric that connects areas apparently disjointed by infrastructures. These connections have a profound social value of regeneration for the residual spaces, and for all those areas that in the near future, when water will not be easily controllable, would be submerged.

Real-time use of the city 3.1.2

The architecture of the city, as well as country planning, depends only on considering the territory as a whole, and maps as the platform on which it is possible to study future actions. So, in order to raise the consciousness of the entirety of phenomena, we need to scale the urban analysis back to the entire city, or the entire source of catastrophic event. In doing so, we shall be able to compare phenomena and areas over time, depending to the level of risk. The necessity of an adaptive tool is due to the unpredict-

[11] Giovanni Battista Piranesi (1720-1778), *IL CAMPO MARZIO DELL'ANTICA ROMA – The Campus Martius of Ancient Rome* (1762), 445 x 235 mm; *ICHNOGRAPHIAM CAMPI MARTII ANTIQUAE URBIS – "Ichnographia" or Plan of the Campus Martius* (1756), 1350 x 1170 mm.

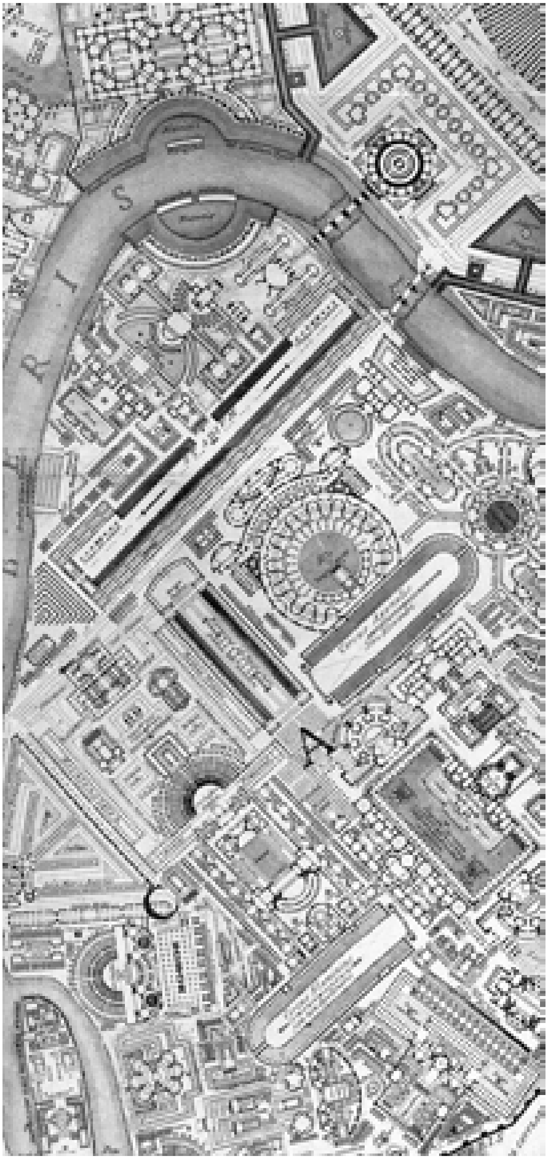


Fig. 3.1
IL CAMPO MARZIO DELL'ANTICA ROMA – The Campus Martius of Ancient Rome (detail), Giovanni Battista Piranesi, 1762.

ability of forecasts. Through the use of a multi-layered dynamic tool, it is possible to represent a reality that has to come, whereas current flood risk maps are usually provided based on information of past events or static models.

Flood hazards change quite frequently, as urban growth continuously changes the fabric of the city. The reassessment of traditional maps is not sufficient anymore to guarantee continuity in the city planning process. Giving a method of assessment instead of a solution-providing tool, it is possible to cope with all these changeableness: the flexibility of the tool determines flexibility of outcomes too, besides the replicability in a number of cases. Moreover, the ability of gathering different maps, simulations and instant open data increase people's hazard awareness by providing access and distribution. Hence, through this strategy it is possible to unify and simplify operative defence solutions capable to reconnect the structure of the city with its main infrastructure, which is the river.

New possibilities in architecture and urban design are allowed by advancements in digital mapping. Given the importance of new technologies in aiding the planning process, it is surprising that Governmental Agencies have been doing very little work trying to connect virtual and physical realities. The architecture of the city depends only on considering the territory as a whole, and maps are the platform on which it is possible to study future actions. Relationship between entities in space-time (Fig. 3.2) is the very nature of things. It concerns 1. distance in non-linear space; 2. emergent features; and 3. links between dimensionally different objects. These relationships are based on the principle of variation, as nothing perpetuates unchanged. (These principles are applied to the cluster analyses of Chapter 3.3.1.)

1. *distance in non-linear space.* Point is the very primitive element of the Euclidean geometry. It is characterised by having not dimensional attributes, such as length, area, and volume; but only by its unique location (x, y, z) in space. Both in two- and three-dimensional space, a point can be related to any another one, and one single line can be drawn. Then, if one direction is given (for instance from point «A» to point «B») the distance between them can be calculated, as numerical descriptions of how far apart objects are. The matter of scale in Immaterial Technologies regards the relationship between one point and the one next to it, because it is not possible to determine the scale of one point in itself. Thus, one of the main issues of the *Telematic Map of Risk* is to make the dynamism of open data visible, as geo-coordinates and features change over time.

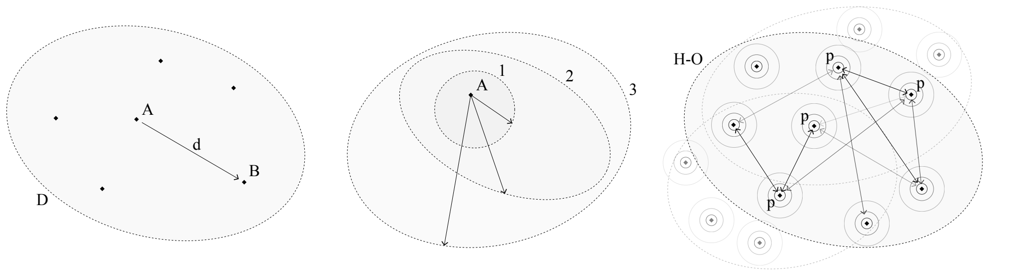
These variations are caused by people's behaviour and the local level of risk, both induced by operative decisions over brownfield and infrastructural developments.

2. *emergent features*. Since information of one single point is meaningless for identifying trajectories, it is impossible to define the risk as an absolute value too. The level of risk is indeed always related to the concausal phenomena—i.e. the possible magnitude of physical events, and the specific features of the territory. These characteristics are strictly connected to people, the natural and the built environment alike. They concern people's behaviours in space-time. As from Einstein's *Relativity* space and time are not seen as emergent properties of objects anymore, the risk cannot be considered a feature of objects either. In fact, hazard is tied to a specific area in a precise instant, and the object emanates a particular level of risk, depending on space-time. It is an inverse relationship between object and space-time: both space and time are inside objects, given that their physical characteristics are the proof of precise spatial and temporal coordinates (see quantum mechanics principles.) Therefore, the risk is not an empty container to put objects, and it does not exist disconnected to other manifestations of phenomena.

3. *links between dimensionally different objects*. Relationships between events cannot be understood just by looking at one phenomenon. In fact, the peril is to miss the width of what T.Morton (2010, 2013) defines «hyperobjects». That is, interrelated things 'massively distributed in time and space',[12] which lay beyond their local manifestations. To focus on one single aspect of reality means loosing the control of surrounding space, ignoring the distance to other events, and misunderstanding the distribution of phenomena. One will not be able to fully understand global warming without connecting all the events that it causes. These are not simply the most visible ones, such as ice melting and water rising, but also those that seems to be very distant. One of the physical circumstances that causes earthquake, for example, is global warming, as water expansion provokes more pressure on the earth crust.

Traditional mapping systems, which were mainly based on static views of reality, analyse fixed states of objects (woods, coasts, houses, mountains, etc.). Before the computer era, the length of time between beginning the mapping of a territory and the end result would have increased the risk of an out-dated map before its completion. As satellites provide

[12] Morton T., 2013, *Hyperobjects: Philosophy and Ecology After the End of the World*, University of Minnesota Press.



1. distance in non-linear space
2. emergent features
3. links between dimensionally different objects

Figure 3.2
Relationship between entities in space-time.

more data, quicker, the platform on which to access and use this data must become more dynamic. Since big data analytics become more advanced, the information becomes easier to extract and utilise. Therefore, traditional maps cannot satisfy current needs any longer. If the correlations between data have changed, and consequentially maps too, politics of spatial management must be modified as a direct consequence. The ability to make instantaneous changes to maps reduces the gap between physical and digital domains. Through the interweaving of these two realms, one could change the awareness of cities' dynamics. Moreover, the direction that strategic planning should take can be better understood.

Urban developments should be tightly connected to risk analysis on digital maps, in order to guarantee flexible planning. This means that urban fabrics—that depend on the infrastructures—will be able to be modified depending on the level of hazards predicted. Thus, these changes shall be set in relation to two manifestations of time: the evolution of the local level of risk, and the local velocity of the building stock transformation. The first indicator varies with phenomena (specifically in this research with global warming) and the possibility of man of intervening on the territory. The timing of this variation depends on the awareness of the community, and on its capability of being prone in improving its resiliency to increasing hazards. The second one is as rapid as the variation of needs of one society can be. In fact, new necessities demand an evolution of the city structure beside the social organisation change, which leads to a building stock transformation.

Tafuri assert with sarcasm that "[a]s a political agent the architect [has] to assume the task of continual invention of advanced solutions, at the most generally applicable level."[13] The use of more comprehensive and holistic tools changes the role of architects. The goal is to provide them a multi-scalar platform allowing for the use of one single dashboard to access multiple layers of information. This will unveil new relationships and connections between buildings and their context. Using digital maps, architects no longer design within a fixed environment, but create infrastructures that allow the urban fabric to change over time. In so doing the gap between maps' time and real world's will be reduced. Specifically, their aim is to merge what is visible and what is invisible, what is material and what is immaterial, and to re-balance the cultural distance between these factors. We are in the phase of being able to understand wide phe-

[13] Tafuri M., 1979, *Architecture and Utopia: Design and Capitalist Development*, The MIT Press, Cambridge, Massachusetts

nomena, and intervening in the environment. Then, the matter of scale assumes a central part of the architects' role.

Three scales are identified in order to fully understand the process of transformation of planning tools and actions for hazard prevention. It is necessary to use a multi-scalar dashboard, and, at the same time, to fix a precise limit in zooming in or out is indispensable too. The multi-scalar platform allows us to use one single dashboard—i.e. a dynamic map—capable to connect the different steps of the strategic planning process. The limit, which is possible as open data are related to the territory, establishes the different steps and the competences that they concern.

To analyse the source of physical risk at the *territorial scale* makes the investigation of the complexity of the whole source(s) possible. At this scale we can analyse the catastrophe propagation, its directions, and spatial entities involved in its dynamics and trajectories.

At the *city scale*, the relationship between infrastructures and the environment is centred on the geospatial comprehension of the local risk, which is related to human behaviours through the *Telematic Map of Risk*.

Then, the very dynamics of change need the *human scale* to become operative devices. Both material and immaterial intervention to ameliorate the *status quo*, and strategic guidelines lower the hazard. With this level of scale, the circle can be closed, as the local variation of the level of risk alters dynamics and trajectories of the catastrophe propagation at a territorial scale.

By creating a hybrid system of design that positions itself between top down urban planning and bottom up city growth, the maps will allow urbanists to create an organised framework within which buildings can be designed. Our awareness of changes to the environment and increasing ability to utilise real-time data allow us to respond to these changes through the design process. Indeed, technologies can be considered as an instrument of democracy, which involves the city as a whole: politics, policies, people's inclusivity, and design. As we live in a democratic society, architecture must be democratic as well, and provide the best frame for human life. Without strategic vision, the way forward is uncertain. It is not even particularly different to the social meaning the high-tech architecture had been promoting from the late Sixties (mainly in the Seventies). That is, anybody can live the High-tech that celebrates the value of the use of buildings instead of the contemplative issue. By renouncing a symbolic role, architecture can become a main instrument of social equilibrium. The telematic use of the city as a scientific dynamic tool—aimed to lower the local risk—rises the value of public spaces, the most democratic ones.

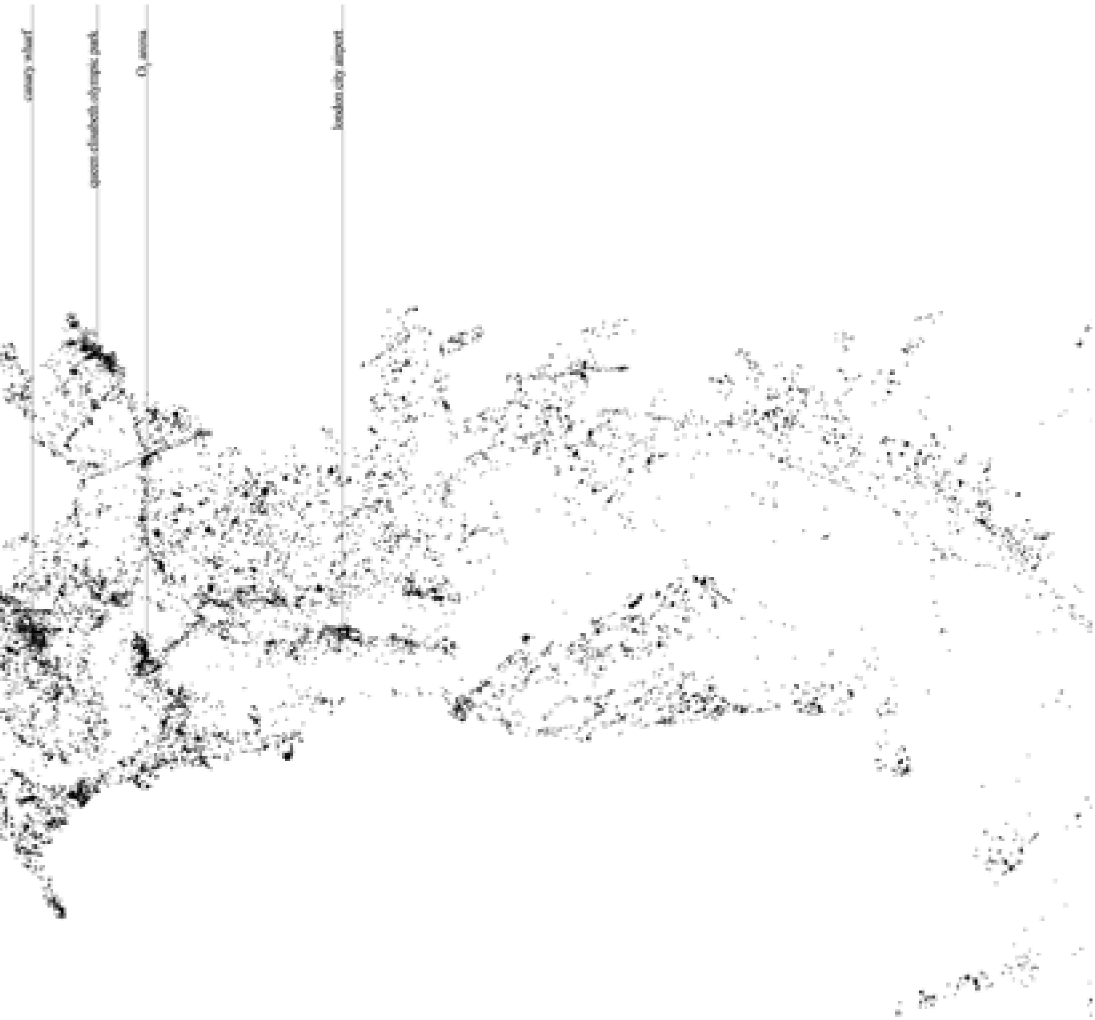
The main aim of the *Telematic Map of Risk* is to use digital techniques to rematerialize reality. It is a navigational platform that collects different kinds of inputs from many databanks onto a dashboard capable to homogenise data as a coherent result. Data manipulation is urban and architectural design together. Even though it might sound an oxymoron, the feeling of dematerialisation of reality due to immaterial technologies is mainly caused by ignoring the connection between virtual and physical reality, and not by the digital world in itself. To underestimate the importance of this relationship means to let catastrophes become disasters with no control. The *Telematic Map of Risk* is an infrastructure of data collection and extraction aimed at merging down information characterised by different output typologies on a GIS[14] support. It is a flexible platform on which it is possible to simplify the density of information present in territory, analyse it and obtain specific guidelines. Here the website and the software used for the map are presented: *Edina Digimap* (http://digimap.edina.ac.uk/digimap/home), for data collection; *Grasshopper* (http://www.grasshopper3d.com/) integrated with *Rhinoceros*, by Robert McNeel & Associates, for real-time people's location; and *Esri ArcGIS 10.3 for desktop* (http://desktop.arcgis.com/en/), for data overlaying and analysis.

All the territorial information about the natural environment, water paths, landform, and the built environment are gathered through *Digimap*. "[It] is a collection of *Edina* services that deliver maps and map data of Great Britain to UK tertiary education. Data is available either to download to use with appropriate application software such as GIS or CAD, or as maps generated by *Digimap* online."[15] *Digimap Ordnance Survey* datasets provide maps at scales ranging from 1:1,250 up to 1:750,000. After having selected the area of interest in Great Britain, one can download a number of tiles of the selected layer, and download them in many formats, depending on the kind of map requested (See Annex B, Section A3). From the tiles gathered via *Edina Digimap*, a structure of CAD layers is created to be exported onto *ArcGIS*. These layers are boroughs' borders, the built environment, green areas, and water paths. Then, the landform is extracted as shape file, in order to understand tidal, river, and groundwater flood phenomena. (See Ch. 3.1.1.)

[14] A Geographic Information System (GIS) integrates hardware, software and data for storing, managing, interpreting and visualising geographically referenced information (maps, charts, simulations, etc.). A GIS looks at data in a way that is quickly understood and shared.

[15] From http://digimap.edina.ac.uk/webhelp/digimapsupport/about.htm

Plate 3.8
People’s map over the study area, within the FWAA.



The innovative aspect of the *Telematic Map of Risk* is the connection of flood risk due to the landform, and the concentration of people in one area. While we can predict the level that water will reach in a certain number of years, we are not able to foresee how and where people will be moving around the city in future. Yet, we can analyse their movements day by day with absolute precision, in order to understand the relationship between humans, water paths, and at-flood-risk areas. One of the possible methods is through *Rhino Grasshopper* and the plug-in *Mosquito*. This component allows extracting posts on social network such as Twitter, Facebook, and Flickr, and selecting just the geo-located ones, so that the precise geographic coordinates of one user are known. Of course, the longer data is collected, the more accurate series of clusters can be evaluated. Processing is perhaps better to gather social media data, but it is not a CAD software, thus make the harmonisation of data (one of the strengths of the *Telematic Map of Risk*) more difficult.

For the entire case study area—from Fulham to Woolwich—one week of Twitter[16] posts are accumulated. Naturally, only the georeferenciated ones have value for our analyses, in order that just the coordinates within the Flood Warning and Alert Areas (from the level of risk R1 to R5) were considered. So for instance, 143 tweets in a 10 square meter area does not imply that that area has being walked on by 143 people. The meaning of this operation is not to know where each single person is at a given time, but to understand their average distribution in the space-time. Indeed, the aim is to compare the different crowd levels between one area and another. The 105,245 coordinates collected in one week time trace the main transportation systems, financial areas, recreational areas, and so forth (Plate 3.8). The highest concentrations of people correspond to transport hubs, such as Hammersmith, Waterloo, and the London City Airport; parks and pedestrian walkways, such as the Tower Bridge Riverside and the Olympic Park; and financial centres—above all, Canary Wharf. Streets and bridges are defined too, by people posting on Twitter during a walk, or sitting on a bench. Also the cable car (Emirates Air Line), connecting the O_2 Arena to the Royal Victoria Dock, can be seen crossing the Thames. And, of course, the tweets-emptier path of the river reveals itself as the real spine of the city.

The entire city and its dynamics can be analysed and understood through the real-time relation between people and space (mainly the built environment). This dynamic media shall give a substantial contribution

[16] Twitter, Inc., 302 million active (May 2015).

in shaping the city of the future, with the highest level of flexibility ever reached. Tafuri's thorough reflection on the possibilities opened up by the self-advertising nature of cities sounds utterly prophetic:

> "Modern urbanism—inasmuch as it is a utopian attempt to preserve a form for the city, or, rather, to preserve a principle form within the dynamics of urban structures—has not been able to realize its models. [...] The city as an advertising and self-advertising structure, as an ensemble of channels of communication, becomes a sort of machine emitting incessant messages: indeterminacy itself is given specific form, and offered as the only determinateness possible for the city as a whole. In this way form is given to the attempt to make the language of development live, to make it a concrete experience of everyday life."[17]

As people are windows on the city, making its parts alive, rivers are alive entities too, changing in morphology and flow over time. Almost any urban aggregate grew up on a river. Cities' prosperity is strongly connected to the use of water paths, as they were used as transport system, to irrigate the soil, and as an essential source of food. Thus, humanity has always dealt with engineering works to control rivers, canalising water paths to make fertile ground, and protecting settlements from the destructive force of water. All human activities were centred on water and the majority of cities were centred on rivers too.

It is very unlikely to find a river or canal sharing two cities or even two countries width wise, because riverbanks have always been the most suitable places where to build villages, towns, and cities. To ascertain that water paths are often the set of boroughs' boundaries seems to contradict the connecting power of water. This disconnection is the reason of different environmental treatments of riverbanks, and also of considering only the riverside as an important issue. In fact, it is quite rare to find common strategic plans between different boroughs along a river or a canal. How challenging the inversion of strategy would be. The *Telematic Map of Risk* operates beyond political divisions; it is only focused on territorial connection. To understand entities, correlations on the map lead to considering the connective objects and not the dividing ones. In so doing, water cannot be considered as a boundary anymore.

[17] Tafuri M., 1979, *Architecture and Utopia: Design and Capitalist Development*, The MIT Press, Cambridge, Massachusetts

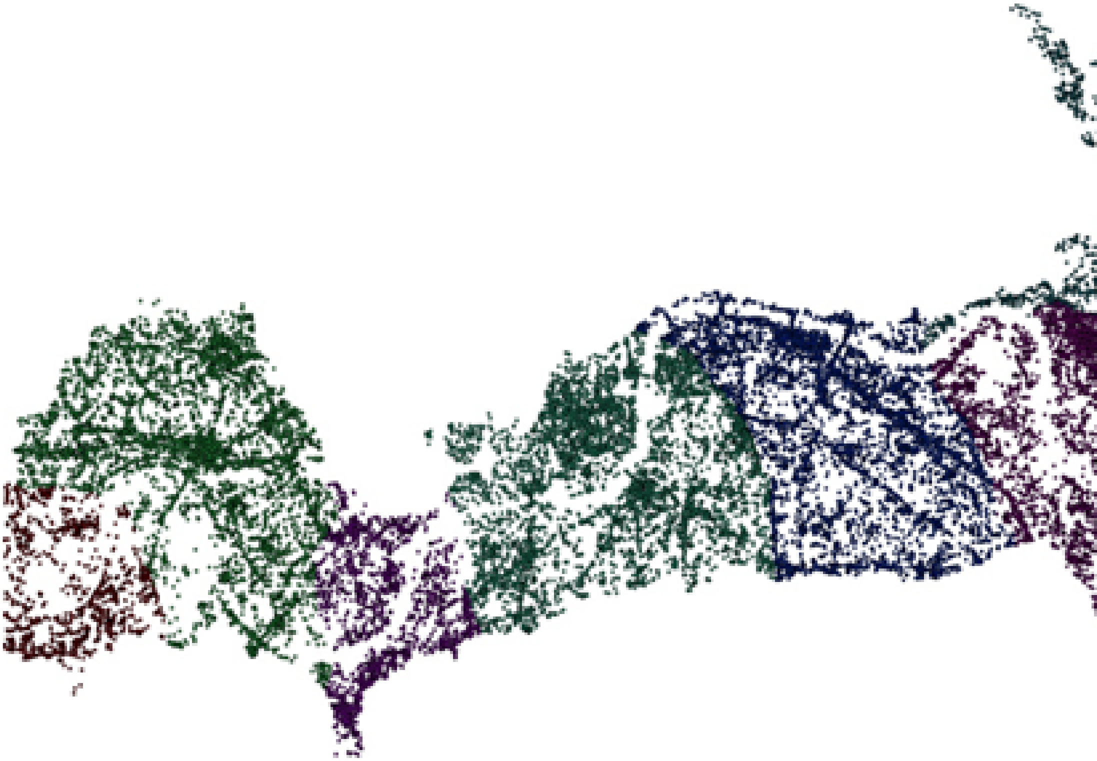
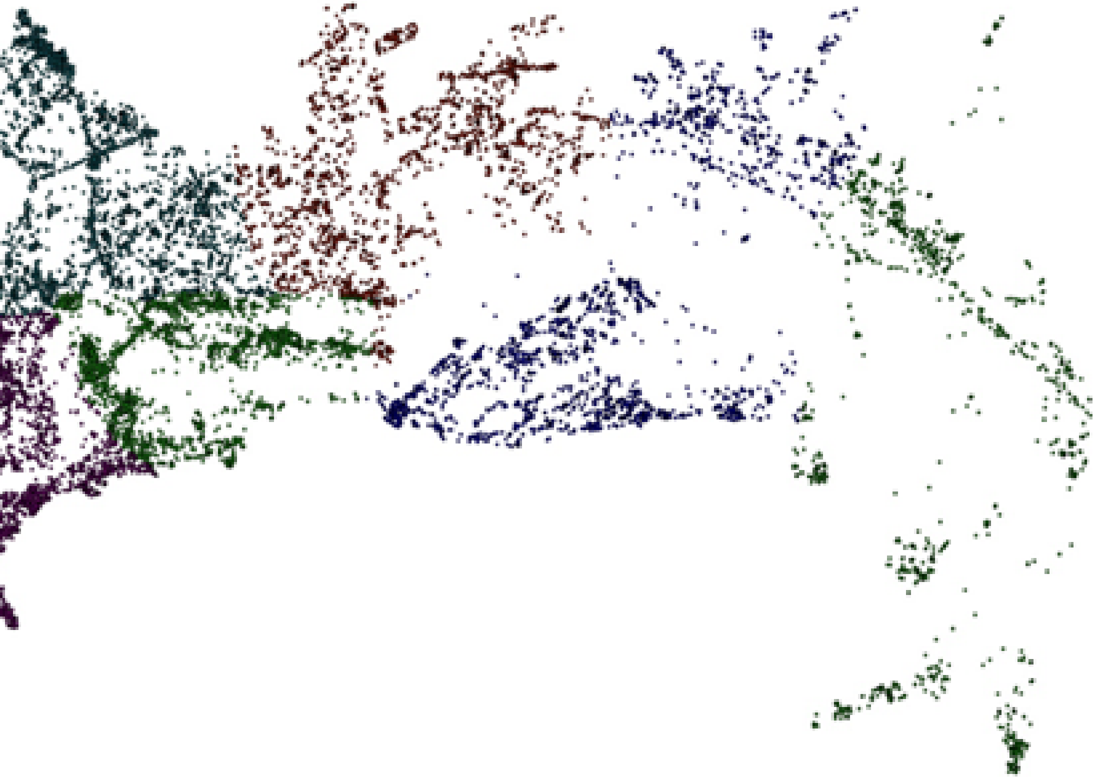


Plate 3.9
Definition of the Water Boroughs.



Boroughs' redefinition based on enclosing land
currently divided by water and people's clusters

Plate 3.10
People's cluster analysis for each level of risk (R1 to R5).

High-clustering, Low-clustering, and outliers
for each level of risk (R1-R5)

To redefine boroughs depending on water paths and people's use of land might be seen as a utopia. In fact, one could consider surreal that new social dynamics connected to the territory prevail over political boundaries. But as the switch from political to socio-territorial perspective happens, the utopia can be supported by entities capable to bridge these two aspects. That is, giving a methodology to modify the environment, the political boundaries can be superseded. Indeed, interventions to transform infrastructures and urban fabrics can connect different areas and boroughs currently cut apart by water paths. The planning of building construction and urbanism can be mediated with programs of social re-organisation. In Plate 3.9 people determine the boundaries of social boroughs. So, it is the less populated area, and any kind of socio-physical cut that shall be consider the core of the neighbourhood, whereas most often watercourses, railways and highways are the splitting entities. The identification of new boroughs based on non-political reading of the space is aimed to put water management as the centre of cultural debate for those cities whose life is strictly connected to the use of their rivers and canals. Water does not know what boroughs and frontiers are: we must re-organise the system to guarantee flood resilience to our communities.

The core of the strategy is about breaking the relationship of the existing status, that is not always a controlled order. It has to be a holistic approach, as it regards the whole system: the change regards the totality, the whole landscape. Utopia is undeniably nothing other than a structured vision of the reality capable to work on a diverse and higher level (M.Tafuri, 1979). This critique to traditional planning process necessities, though, to turn the utopia into project, while so far any utopia remained a stunning drawing. Cities change faster than we imagine and we have the chance to improve the condition of future liveability of spaces. Yet, the rapidity of city changes allows also for negative urban situations to be turned into potentials for future networks of developments. To make this happening, flood resilient guidelines shall be the connectors to bridge fragmented areas of the city (Ch. 3.2.2). The total re-organisation of the urban system becomes design process in the mere sense of an organic vision of the city. But, again, we must study the entire city before planning on a smaller scale.

Spatial analysis, whose methods shall be detailed in Chapter 3.1.1, in the pilot case site study, can show us the **cluster** analysis, referred to each level of risk. Clusters' map recognizes statistically significant hot spots, and spatial outliers, using the *Anselin Local Moran's I* statistic. Through these tools, new boroughs can be identified (Plate 3.10). These do not re-

cluster *is a group of data objects that is more similar to each other than to those in other groups, in terms of position or similar values.*

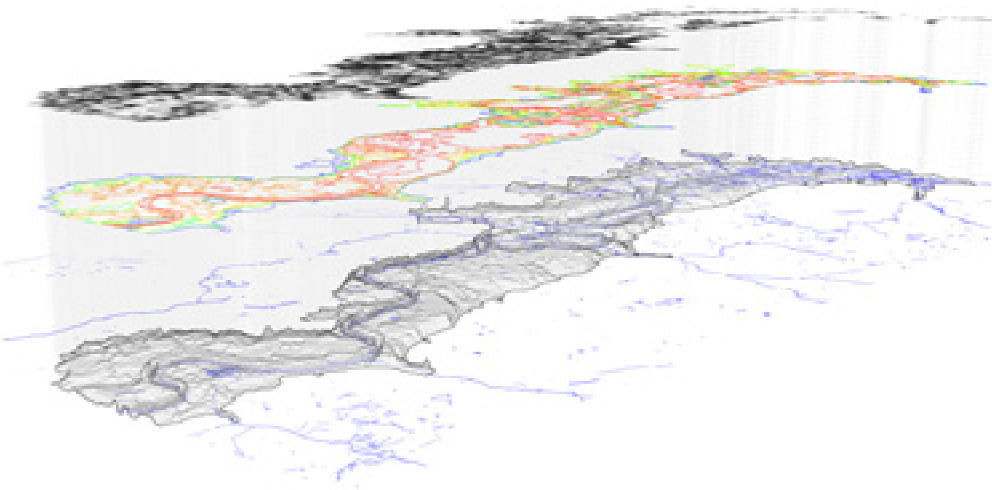


Fig. 3.3
Spatial correlation between Twitter data and the five levels of flood risk.

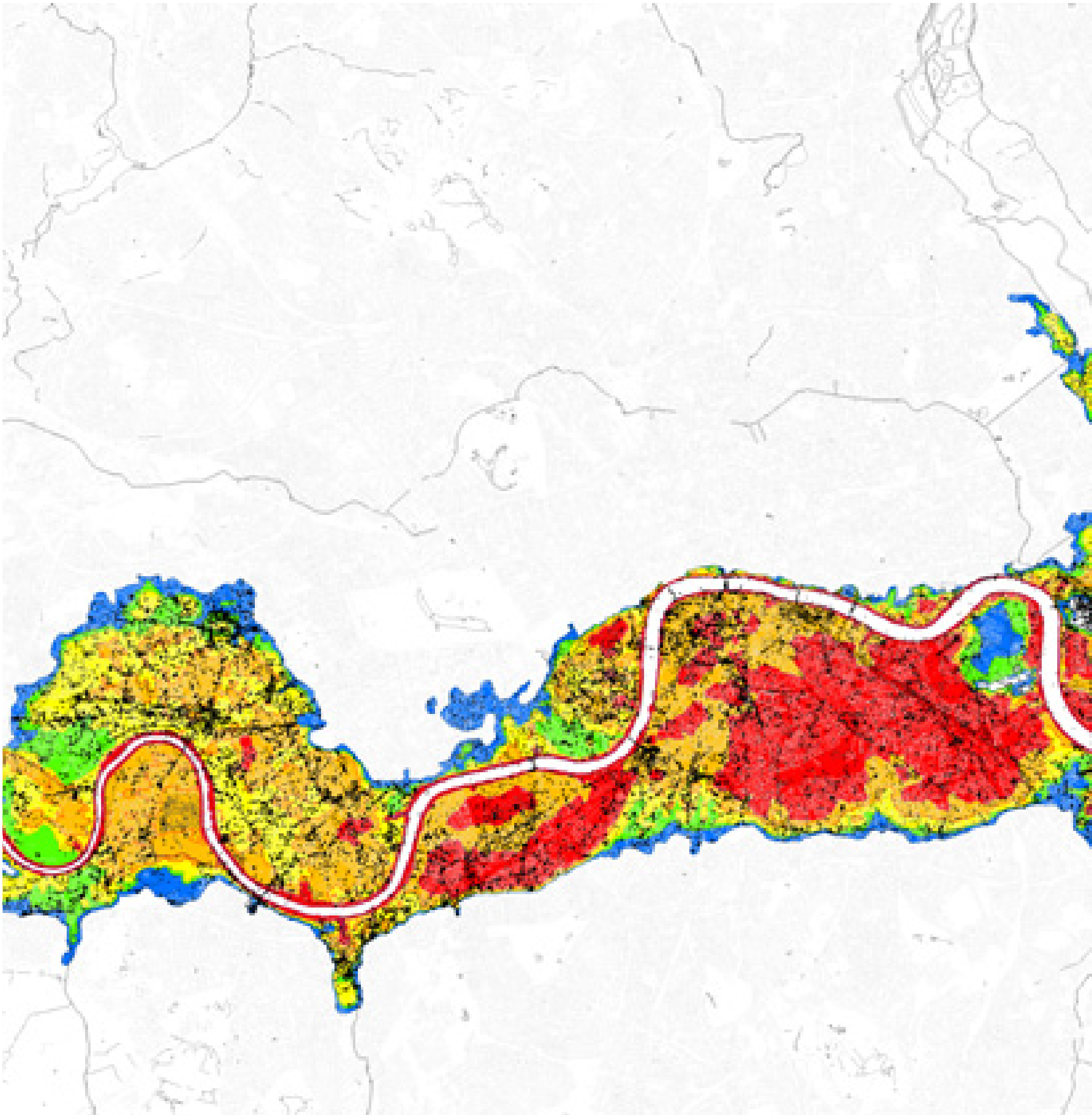
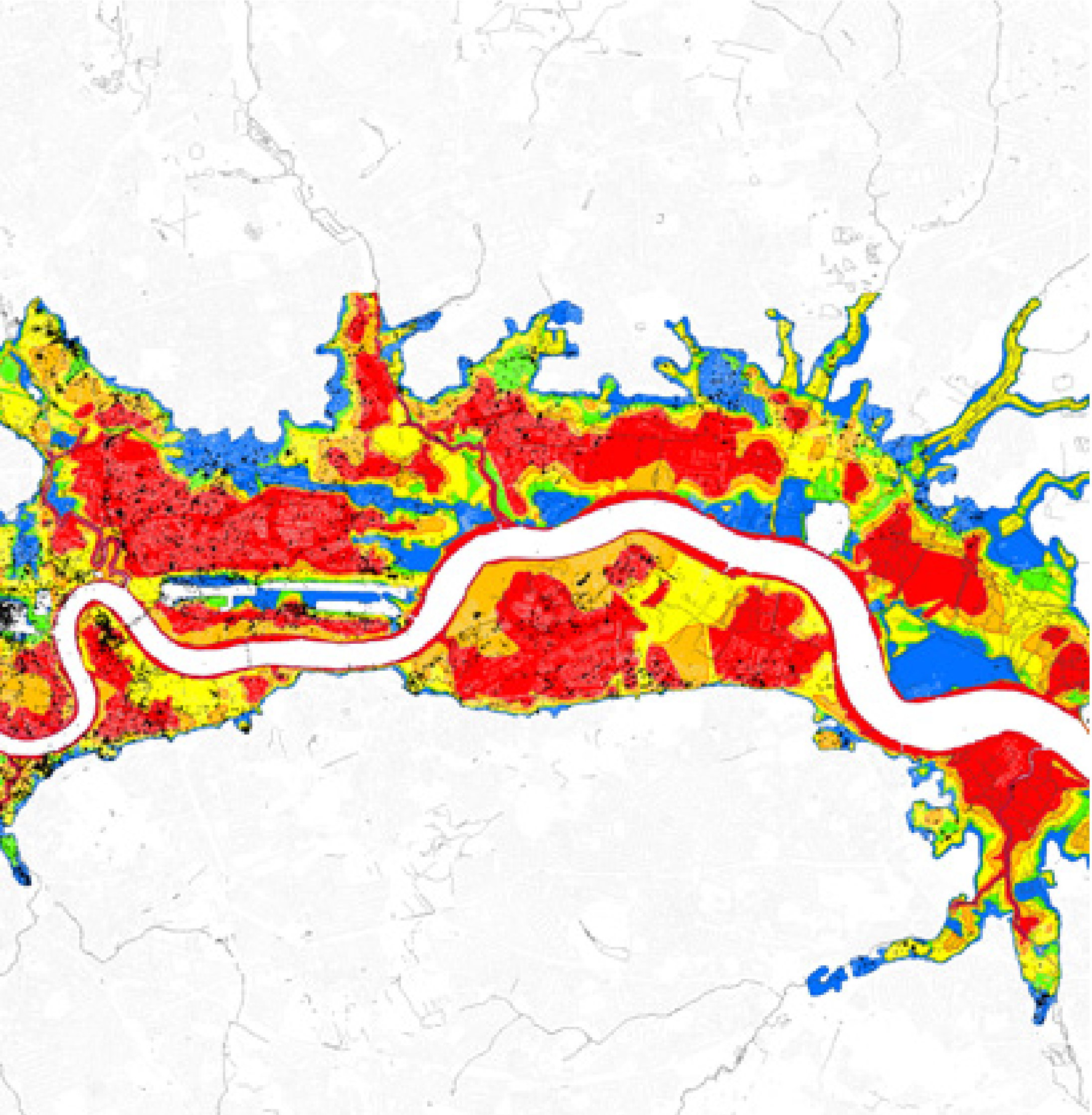


Plate 3.11
Levels of risk and people location based on twitter posts on London's map.



geo-referenced tweet
100 cm lower
50 cm lower
+ **84 cm** *flood level 0: Barrier failure
50 cm higher
100 cm higher

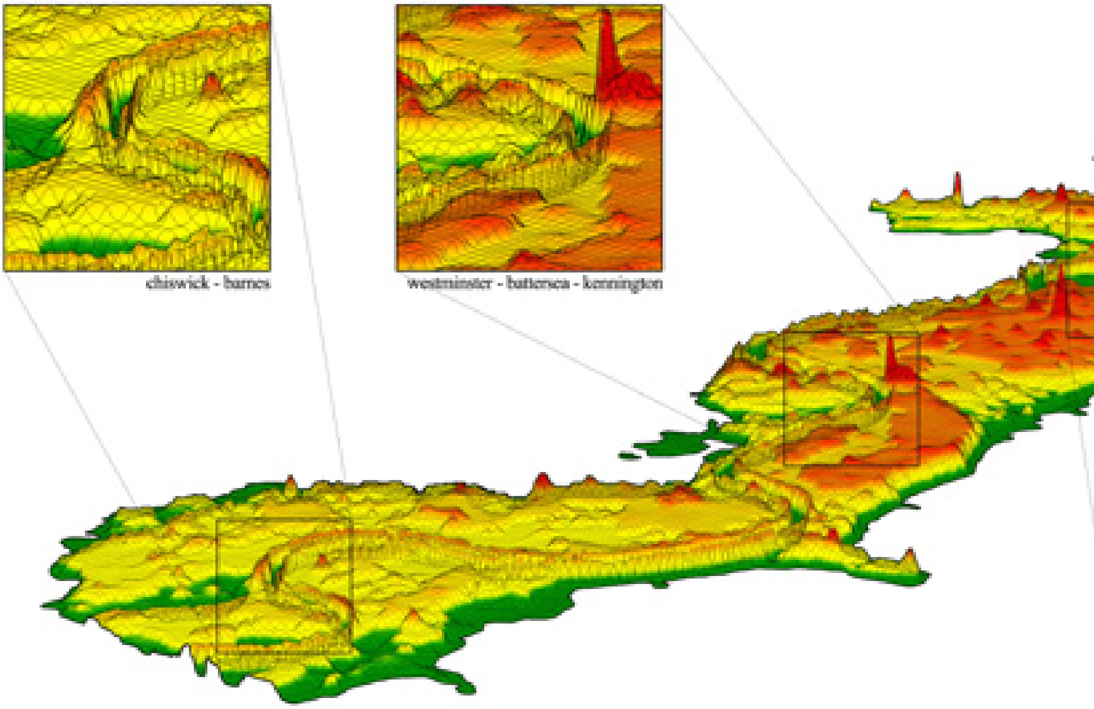
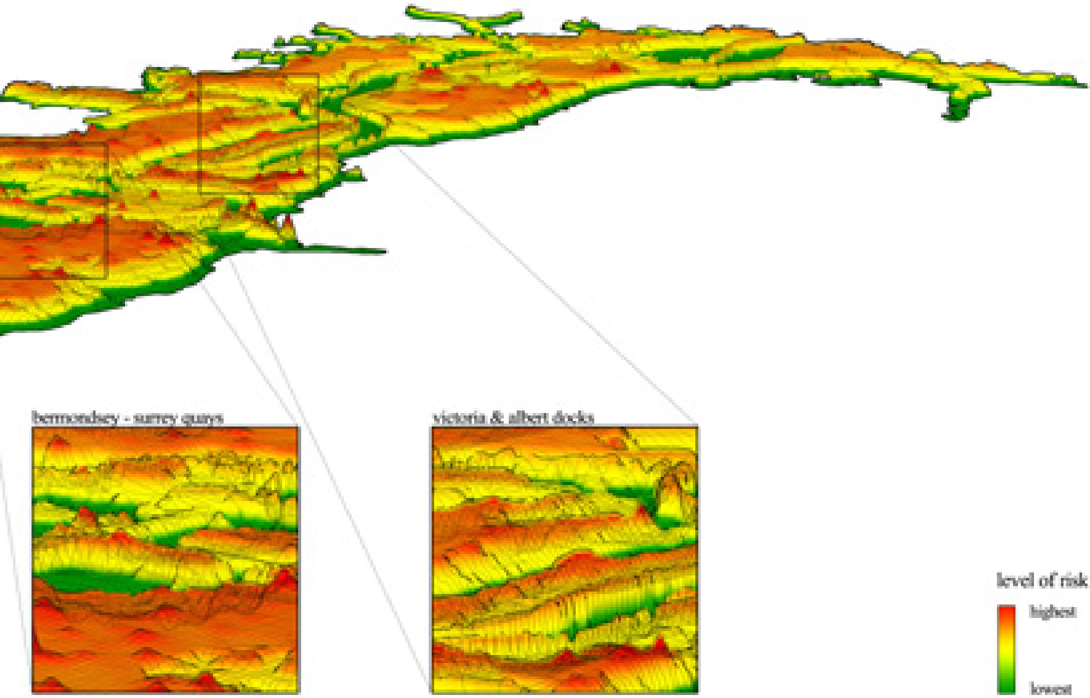


Plate 3.12
The Telematic Map of Risk, 3D flood risk analysis.


bermondsey - surrey quays
victoria & albert docks
level of risk
highest
lowest

spond to politics but to social policies in connection to water infrastructure. Within these water-boroughs new developments shall be driven using detailed guidelines specific for each local level of risk. This tool helps in identifying the priority of intervention across the FWAA. But to rethink the forms of information gathering is not enough: we need to improve the way information is transformed into knowledge, and we need to use knowledge for action on the environment.

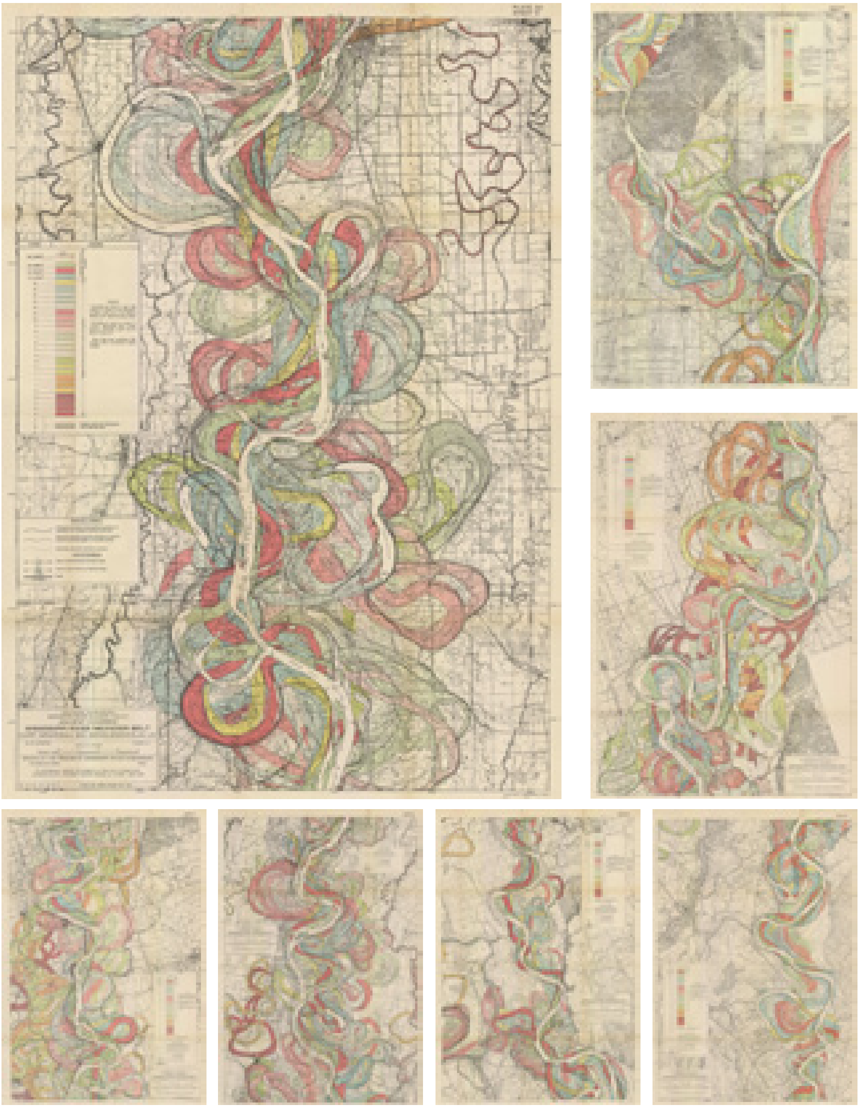
Once all the useful data is gathered from the *Digimap Ordnance Survey* dataset, divided into layers, they shall be correlated to people's location onto the GIS software (Fig. 3.3, Plate 3.11). The way technology is involved in 'human body's experience' (P.Clough, 2008) is thus put in relation to standard methods of environmental data gathering. It is a solid democratic system based on the spontaneous interaction with the environment by the human-technology interface of GPS. Digital interfaces humans with the digital environment, in order to provide complex information on which strategic planning is going to be based.

Two main aspects emerge from the *Telematic Map of Risk* (Plate 3.12). The first one regards the River Thames, which is the real source of hazards for London. It is evident from the map that the level of risk along the river defines the shape of the river itself, contrary to the rest of the FWA, where physical features do not perfectly match with the risk levels. This is so, because the risk on the Thames is equal to zero within the R1-R5 range. Paradoxically, the level of risk on the river would be higher in case of drought. This condition highlights the theoretical good nature of the watercourse, while the risk correspondent with its banks rise promptly, to slightly decrease few meters ahead. The maxim peaks represents the areas where an important concentration of people aggravates the high level of risk. The methodology for the creation of the four-dimensional *TMR*, on *Rhino Grasshopper,* is detailed in Appendix B, A4.

The use of the *Telematic Map of Risk* as operative tool shall become the engine of planning decisions at all scales, since the GIS base is a dynamic support. The multi-layered structure allows the extraction of data from one site where a development, or a renovation, is supposed to take place. The information obtained from this log can be compared to areas with same features and level of risk, so that common strategies and actions can be adopted. All the layers interwoven shall lead to strategies and technologies to be applied to areas of development both for infrastructures and the structural architectures of the city, such as dwellings, service buildings, etc. When applied to the built environment, structural interventions modify the local level of risk, and infrastructural adaptations change the global one. In doing so, the telematic map is automatically updated, as new data are put into the layered dataset.

Notes

[5] The visualization of the living River Mississippi by Harold Fisk, 1944.



[11] "We must verify our observations in the very heart of the structure the Campo Marzio. It is immediately apparent that this structure is composed of a formless heap of fragments colliding one against the other. The whole area between the Tiber, the Campidoglio, the Quirinale, and the Pincio is represented according to a method of arbitrary association (even though Piranesi accepts the suggestions of the Forma urbis), whose principles of organization exclude any organic unity. Only the areas to the northeast and southwest, included in the double bend of the river, seem to be recomposed into structures in some way unitary and well defined: two orthogonal axes, roughly parallel to the course of the river's bend, guide the composition of the Sepulchrum Hadriani [Hadrian's Tomb), of the complex formed by the two circuses of Hadrian and Domitian, which extend along the axis of the mausoleum, of the Circus Agonalis, of the Circus Flaminius, of the Templum Martis, of the Gimnasium Neronis, of the Terme [Baths) of Agrippa. A second alignment, regulated by a rectilinear axis, is found in the northeast sector. Prelude: "Apocalipsis cum Figuris" Here we come upon a succession of groups of monuments, totally without archaeological basis and characterized rather as public facilities: the Porticus amoenitati annexed to a gymnasium, the Naumachia Domitiani, a triangulation of areas of green, protected by the "statuae virorum illustrium" and connected to a natatio, it, too, triangular, open on the other side of the Pons Fabianus. [pp.34, 35]

The ambiguity of the Campo Marzio now becomes evident; it is at once a "project" and a denunciation. As a disenchanted documentation of the impossibility of an unambiguous definition of language, it--projecting this situation into the past--sounds like a merciless satire of the infinite capacity of late-baroque typology to reproduce itself metamorphically. (The fact that in the Campo Marzio the allusion to baroque typologies is filtered through a classicist geometrism fools no one; it is simply a means of rendering metahistorical and universal the polemic already begun.) Inasmuch as it is--despite everything--an affirmation of a world of forms, the Campo Marzio, precisely because of the absurdity of its horror vacui, becomes a demand for language, a paradoxical revelation of its absence.
Negation and affirmation cannot split apart. The "naïve dialectic" of the Enlightenment is already superseded.
The "great absentee" from the Campo Marzio, then, is language.
The absolute disintegration of formal order, of what remained of the huminist Stimmung, of its sacred and symbolic values--and, above all, of perspective as a symbolic instrument for the quantitative control of space--logically also affects the subject of Piranesi's work: the relationship be-

tween history and the present. On one side, there is painstaking , scientific study of archeological findings; on the other, the most absolute arbitrariness in their resolution. (In this respect, after all, the Campo Marzio is anything but an exception in Piranesi's work.) History no longer offers values as such. Subjected to a merciless inspection, it is revealed as a new principle of authority, which as such must be disputed. It is the experience of the subject that establishes values; in this, already lies all the aspiration to the negative polemic of romanticism. Is Piranesi the "archeologist" interested in caves, underground passages, and substructures purely by chance, then? Rather, cannot this interest in "what is hidden" in ancient architecture be interpreted as a metaphor for the search for a place in which the exploration of the "roots" of the monuments meets with the exploration of the depths of the subject? [p.38]

(Tafuri M., 1987, The Sphere and the Labyrinth - Avant-Gardes and Architecture from Piranesi to the 1970s)

Re-form the relationship with water

Future flexibility in planning current cities 3.2.1

In view of Buckminster Fuller's conviction that the certain and inexorable progress of societies pass through innovation in technology, we must be aware that architectural technology is currently driven by the use of data. Models facilitate any computational, speculative, and modelling process. 'Without models there are no data.'[1] Because of their very nature, models need flexible platforms in order to fully be used and analysed. Being volatile rough material, it is very adaptable, and the information we can obtain from it depends on the correlations we may be able to establish.

> "Systems of values can no longer be considered established for long periods. What can be wanted depends on what can be made possible, and what must be made possible depends on what is wanted. Ends and functions of utility are not independent measures. They have a relationship of implication in the decisional ambit. Representations of value are controllable within broad limits. Faced with the uncertainty of future alternative developments, it is absurd to wish to construct rigid decisional models that furnish strategies over long periods.[2]"

1 Edwards P.N., 2010, *A Vast Machine. Computer Models, Climate Data, and the Politics of Global Warming*, The MIT Press, Cambridge, Massachusetts.

2 Rittel H., 1966, *Forschungsplannung*, Oldenbourg Verlag, Munich, pp. 110-129.

Telematic and urban infrastructures requires the same degree of flexibility, as predictions of future phenomena can be easily altered by unforeseen events that are capable of the entire system's collapse. For sure, we are aware that our planet is facing a dramatically rapid increase in the magnitude of catastrophes and disasters, due to global warming. The climate and the territory we live tend to coincide nowadays, as one affect the other, and one is the effect of the other. This scenario involves both the scientific and the intellectual levels.

Today, the immense amount of historic data allows us for deep knowledge in most of the scientific fields. The techno-centricity—*τέχνη* as the art of inventing, of crafting— and socio-centricity of this dissertation has its roots in considering *Immaterial* and *Architectural Technology* as a *unicum*. There cannot be any future development on a city scale that is not going to be driven by something larger, and there cannot be any territorial change that is not going to be strictly connected to local mutations.

The technology-driven approach to territory diminishes the disconnection of different interventions and developments, in favour of organic and transient implementing programmes. On an epistemological level, data and information are substance: they are the material by which every change is re-shaped. Cities and their communities are, thus, the real terrain of change, the dynamic worksite where their parts evolve continuously. This high-tech dynamism displays the highest level of flexibility. The city is the landscape of variation, where objects and people are in constant motion. Nothing rests, nothing perpetuates unchanged. Hence, the crucial issue of dynamism and transience draws attention to the question of time.

As the Theory of Relativity got rid of absolute time, the consequences had an impact not only on the scientific community, but also on the philosophic and behavioural side. Everything becomes relative, since time runs at different speeds, depending on the space. And if any human action is set within an individual space-time, any human action is relative to the observer, to the place, and the time that any action occurs. The dynamic quality and quantity of space and time involve the entirety of phenomena: 'when a body moves, [...] it affects the curvature of space and time—and in turn the structure of space-time affects the way in which bodies move and forces act.' (S.Hawking, 1988) As space and time factors assumed new connotations in relation to spatio-temporal entities, also architectural design has undergone structural changes. From the 1960s, time and acceleration entered the architectural debate, and the whole design process. The 'architecture of becoming' characterised the philosophy and design of many architects and groups, first among those Archigram (*Plug-in City*, 1964; *Walking City*, 1964; *Pompidou Centre*, 1971-1977), Cedric Price (*Fun Palace*, 1961; *Potteries Thinkbelt*, 1966; *Detroit Thinkgrid*, 1969), Archizoom (*No-Stop-City*, 1969), and Bernard Tschumi (*Parc de la Villette*, 1982-1998).

The transient state that defines metamorphic entities like the city determines its evolution over time. As opposed to nomads, who are part of a nonlocal system, urban developments have got specific locations. These, even transitional, are local manifestations of urban processes, with their temporal features. Yet, as nomads, cities acquire a trajectory as one of its components moves ahead. Variation is a reality to us because our whole culture is a tradition of stratification and change, where there is no real opposition to innovation and evolution—as the very meaning of progress is not a rush, a competition *tout court*, but always a dialog with the *status quo*. The self-organised processes that characterise cities' developments leave traditional plans and planning regulations with an aura of overbearing and out-dated ideas—frequently ideologies. By pointing out that 'history is always written from a sedentary point of view, [...] even when the topic is nomads',[3] also Gilles Deleuze and Félix Guattari highlight the urgency to change the way we look at events.

Whereas forecasts and foresights are steady methods of preparedness to future events, anticipation is based on non-predictive tools. The first two approaches are deterministic predictions that close or limit further analyses and variation. Anticipation works as an open system capable to adapt its infrastructure to the forthcoming change. Thus, infrastructures ground their openness on the possibility of change, and not on the possible change, being flexible and anticipatory.

> "By specifying what must be fixed and what is subject to change, they can be precise and indeterminate at the same time, they work through management and cultivation, changing slowly to adjust to shifting conditions. They do not progress toward a predetermined state (as with master planning strategies), but are always evolving with a loose envelope of constrains."[4]

Flexible infrastructures do not work for particular buildings on specific sites, albeit they define the site itself, and are adjustable to the site.

[3] Deleuze G., Guattari F., 1987 (1980), *A Thousand Plateaus. Capitalism and Schizophrenia*, University of Minnesota Press Minneapolis.

[4] Allen S., 1999, *Points+Lines, Diagrams and Projects for the City*, Princeton Architectural Press, N.Y., p. 88.

Furthermore, they guarantee each space its own autonomy. The ground for future developments is prepared by infrastructures, which also determine the quality of these changes. Infrastructures divide, serve, and network at the same time every place they are connected to. In fact, they have the extraordinary task of dividing pieces of land different in quality, height, use, and ownership; they provide public services linked to either the specific use of land, or the use of the infrastructure; they establish a network between different areas, with the aim of facilitating communications, mobility, and exchange.

Flexibility and its manifestations are in tight connection with the idea of movement, mobility, and circulation. They are the base of urban planning, and represent the social answer to the need of being in different places over the day. Infrastructures also connect ideas, information, and knowledge even at thousands miles distance. Mobility does not simply mean the use of roads, railways, and the tube. The most important thing about mobility is the adaptability of connective and circulation systems. That is, their allowing for space enjoyment no matter what the conditions to the contour are. Physical and immaterial infrastructures form the community itself. This means that there is no complex society whose orderly functioning is disconnected to the use of infrastructures, as they network structural manifestations of the community life. Indeed, they are the 'basis for a pattern of growth' (P.Smithson, 1955), resembling human organisms with its nervous system, an automatic continuous loop of messages—in fact, the very definition of **cybernetic** systems. Infrastructures guarantee the flow of people in any city, region, and country.

cybernetics *is the scientific study of control and communication in the animal and the machine, a transdisciplinary approach for exploring regulatory systems, their structures, constraints, and possibilities.*

Digital infrastructures, as well as nervous system, work from the individual to the collective, and then back to the individual again, in order to create an endlessly adapting interconnection of complex structures. They drive architecture to a higher level of complexity, centred on the problem of perpetual adaptability. It is nothing different to the historical way to evolve the city. The matter is only about the forms of anticipation, which need to be guided by dynamic platforms, because global phenomena are tackling our environment more frequently and with a higher magnitude than in the past. Consequently, a larger number of people are affected by these events. Physical and telematic infrastructures must respond adequately to the challenge, integrating widespread structural changes with infrastructures. 'Permanence and instability' (Stainer H.A., 2009) represent the two dichotomous aspects of architectural technology, which regards built and digital architecture with no distinction at all.

> "Infrastructural work recognizes the collective nature of the city, and allows for the participation of multiple authors. Infrastructures give direction to future work in the city not by the establishment of rules or codes (top-down), but by fixing points of service, access and structure (bottom-up). Infrastructure creates a directional field, where different architects and designers can contribute, but it sets technical and instrumental limits to their work. Infrastructure itself works strategically, but it encourages tactical improvisation. […] Infrastructures accommodate local contingency while maintaining overall continuity. […] Infrastructural systems work like artificial ecologies. They manage the flows of energy and resources on a site, and direct the density and distribution of habitat. They create the condition necessary to respond to incremental adjustment in resource availability, and modify status of inhabitation in response to changing environmental conditions. […]"[5]

Everything depends on how infrastructures are de-structured. The city interests us for its variation, right as music capture our attention for what is going to happen next. Indeed, we are always in tension between what one note make us thinking the next one is going to be, and what it will be in reality. The constantly changing parts of the cities are connected to the more permanent ones, but their design has often been separated. Contemporary cities' strategic vision is based on keeping the private land distincted to its connective webs. This means a different control of the two components, even though there is not a precise demarcation line. One may consider it more as a thick boundary, varying in thickness depending on the specific characteristics of any place. This flexibility of control causes a reaction from inhabitants that leads to a global interaction, as people can work within a varying space, over time. It is a matter of both physical and temporal scale that involves communities, designers, and Authorities alike. The pragmatism of this system is fortified by a series of spatial features specific to the interventions onto the built environment, the land, and water paths.

Walking through a park, cycling along a river, driving across a city, commuting on the tube, sailing over a river, or travelling on the train, one is using public land, and precisely public infrastructures. The main aim

[5] Allen S., 1999, *Points+Lines, Diagrams and Projects for the City*, Princeton Architectural Press, N.Y., pp. 80-82.

of each infrastructure is to keep people safe during their journey, and to connect a place to another. This may seem obvious, but at least one of the two points is often disproved. Moreover, individual movements—the way people move and where they travel to—are the main indicators of patterns of land use and activities in a city. People's walking, jogging, bicycling, etc. say a lot about public and private areas, as seen in Chapter 3.1.2. This complex web reveals multi-directional interactions, to connect all the accumulated parts of the city. Dealing with non-centralised systems—and, thus, with non-centralised controls and plans—, we may have an infinite amount of local looped systems. Even if vast and complex, the system has to be defined and closed, for not incurring into urban sprawl conditions.

The proposal is also about human-centred soft infrastructures. Beside the more conventional forms of infrastructures (roads, railways, etc.), a number of less tangible technologies create the background of the reality we live in. Digital devices, exponentially increasing in number of data exchanged, and the Internet of Things (IoT) form an invisible infrastructural network of information collection, analysis, and outcoming models.

The city as a whole is the combination of its many parts, and its many network systems, which are complete in themselves but missing of their connective potential. Cities' distinctiveness lays at the core of the adaptation capacity of its spatial entities. The anticipation of structures, depending on digital-behavioural inputs, forms the unifying point of top-down and bottom-up approaches to urban planning and architectural design. In the past, the imposition of higher order and logic 'on the layout of human society' (Banham, 1976) caused the complete annihilation of the society itself. Whereas nowadays, the proper use of immaterial technologies—the sources of real-time feedbacks from the material world—represents a much deeper sensitivity to social changes and urban mutation.

existentialism *is a philosophy centred on individual existence, choice, and freedom. It is the view that humans define their own meaning in life, and try to make rational decisions despite existing in an irrational universe.*

Guidelines for territory planning 3.2.2

The attempts of **Existentialism** and Situationism between the 1940s and 1960s had a big impact on architecture and urban condition.[6] The attempt was aimed to centre the manifestation of human existence on the

6 Situationist urbanism had been presented in the *Architectural Review* in July 1958 and April 1960, and had been a theme of Banham's "City as Scrambled Egg", which had appeared in *Cambridge Opinion*, n. 17, 1959.

approach to the world. Coming from the Unitary Urbanism, Situationist Urbanism perceived the opportunity to revolutionise cities into places of popular agencies. In fact, people can go beyond cities' alienation, creating places tailored on their needs, and re-making solid communities. The rise of this 'psychogeographical' perspective affects the way the environment shall grow. Such revolutionary ideas became public practices as the subversive critique developed into social reality.

> "The proletarian revolution is that *critique of human geography* whereby individuals and communities must construct places and events commensurate with the appropriation, no longer just of their labour, but of their total history. By virtue of the resulting mobile space of play, and by virtue of freely chosen variations in the rules of the game, the independence of places will be rediscovered without any new exclusive tie to the soil, and thus too the authentic journey will be restored to us, along with authentic life understood as a journey containing its whole meaning within itself."[7]

Then, with Archigram and the High-Tech Architecture[8], technology became 'the route to individual freedom' (Stainer H.A., 2009). The use of parts coming from the high-tech industry and innovative technologies into building design creates a more democratic status of space, since it is totally inclusive. Digital innovation is bringing people together, telematically but also physically: digital realm is helping in gathering the analogue world. It is very alluring to hope—and hopefully, soon, 'to gauge'—that architecture is one of the instruments and vehicles to join the two territories. The importance of buildings and the outdoor spaces is connected to the infrastructures of a city. Looking at buildings joint with physical and digital infrastructures, we can state that the overall quality of the city depends on how they work together. Naturally, also energy consumption comes from this relation.

Sustainability cannot be disconnected to cities' complexity. And the fact cities are consuming vast green areas every year, in favour of cement, pose the issue of whether infrastructures and the structural parts of the city are working together properly. A city twice denser than another uses about one tenth of energy (Foster, 2008). New urban developments are

[7] Debord G.E., 1995, *The Society of the Spectacle*, Zone, New York, p. 126.

[8] High-Tech leading exponents are (in alphabetic order) Sir Norman Foster, Bruce Graham, Sir Michael Hopkins, Fazlur Rahman Khan, Sir Richard Rogers.

needed to reduce their impact on the environment not just in terms of low carbon emission, but also in regards of natural environment invasion. It is necessary to control cities expansions, as the idea that our finite land was infinite led to uncontrolled sprawl, and ungoverned developments. When in the disaster film *The Day After Tomorrow*—which may seem not to be fictional anymore—, Vice-President R.Becker realise global agendas were totally wrong, he addressed to the nation the famous preachy speech: "For years, we operated under the belief we could continue consuming our planet's natural resources, without consequence. We were wrong."[9] Predictions regarding global warming and its direct effects, and recent water-related disastrous events have focused the attention on water management politics. A holistic approach in managing floods increases the quality of the environment. The two main aspects of the impact of design process are the achievement of sustainable developments, and the increase of flood resilient structures. The ideal is to create infrastructures so flexible in their parts that the city can grow and transform itself without any obstacle.

The *Telematic Map of Risk* shifts the attention of architects from the unpredictability of the rising magnitude of phenomena—and specifically of floods in this dissertation—to the real-time awareness of phenomena themselves. This will be possible only whether the network of infrastructures and the urban fabric provide disaster resilience and the greatest liberty intrinsically. A non-defensive approach in flood risk management must be adopted in order to reduce the **residual risk** lingering from barrier systems. Allowing water to enter the city in a controlled and predetermined manner also increases social awareness, for it involves the commonalty in the adaptation process with the natural environment. People should become active participant in the design of the city to guarantee their own collective integration. Adaptation to flooding allows for the continuity of daily life, besides the reduction of flood consequences themselves. The use of the built environment, especially when a flood occurs, is the very core of this research.

residual risk *is the risk that remains after controls (structural actions) are taken into account.*

To predict flooding is complicated, also because global warming is increasing the magnitude of natural phenomena *nonlocally* (see Ch. 3.1.2). The likelihood a flood event occurs on a specific area is governed by many natural and man-made factors. As the natural ones cannot be mitigated in the mid-short term (see Ch. 1.3.1), the only way to tackle disastrous phenomena is to control the quality of the built and the natural environment. Moreover it is crucial to direct people's behaviour toward the direction of

[9] Emmerich R., 2004, *The Day After Tomorrow*, 124 minutes, 20th Century Fox, Lionsgate Films, New York.

a disaster resilient society. Also continuous changes of the environment have made predictions quite difficult to be kept updated. This is so even though computer modelling is getting more sophisticated—it is almost impossible to keep under control every house built or demolished, every street built, and every inappropriate neighbouring. The opportunity of having a holistic dashboard is crucial. (See Data Collider by Senseable City Lab, and City Dashboard by CASA, UCL.)[10] The definition of the local level of risk shall give guidelines for future development. Taking guidelines as norms means not to modify the risk arbitrarily, but in coherence with the whole area in which the development is going to be built. They also lead to a more in-depth analysis of the local level of risk.

Naturally, low lying and coastal lands are the areas where the impact of global warming would be greatest, and that require the most intense efforts to guarantee adaptation processes. However, the prediction of precise locations for increased flood risk resulting from climate change is difficult, as flood risk dynamics have multiple social, technical and environmental drivers (Few et al., 2004). Floods are divided into five categories (see *PPS25, Annex D*), depending on the source, as follows:

- *Tidal:* sea; estuary; overtopping of defences; breaching of defences; other flows, such as fluvial surface water, that could pond due to tide locking.

- *Fluvial:* inundation of floodplains from rivers and watercourses; inundation of areas outside the floodplain due to influence of bridges, embankments and other artificial levees; overtopping of defences; breaching of defences; blockages of culverts; blockages of flood channels, or flood corridors.

- *Surface water:* sheet run-off from adjacent urban or rural land; surcharged sewers, combined to foul or surface water sewers.

- *Groundwater:* water table rising after prolonged rainfall to emerge above ground level remote from a watercourse; most likely to occur in low-lying areas underlain by permeable rock (aquifers); seepage

[10] http://datacollider.io/; http://citydashboard.org/london/

direct into properties; groundwater recovery after pumping has ceased for mining or industry.

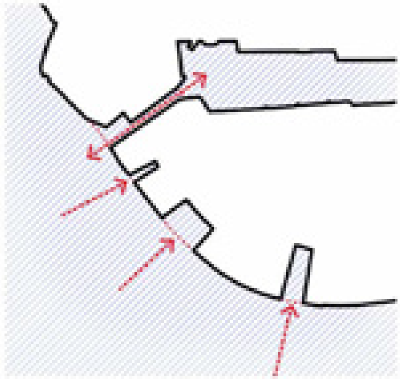
- *Infrastructural failure:* reservoirs, canals, industrial process, burst water mains, blocked sewers of failed pumping stations.

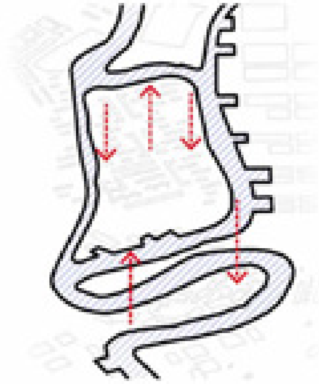
Dikes or barriers generally control water coming from the sea, and these massive engineering works regulate the amount of water passing through. Shifting the focus on the Thames River in London, the Thames Barrier and the planned Estuary Barrier will control the tide coming from east, while the river stream flows from west. So far, only the city centre of London is protected from tidal flooding, whereas the entire metropolitan area is not safe from the other typologies of flooding. To store some flood water is reasonable just in the case of small rivers as it provides benefits in reducing risk further downstream. But generally flood volumes are huge to be stored onsite. Thus, in order to avoid water generating flood upstream, it is extremely important to let floodwater passing through the land (LifE Team, 2009).

After having analysed open data gathered from the Environment Agency's website about water levels and rivers' flow over the critical months (November to February, see Ch. 2.1.2), one can fully obtain information on water dynamics. This means, being able to understand how risky one area is, the delay of water growth in one station in relation to the previous one, the dynamics of locks depending on precipitation, etc. All this information is extremely helpful in designing adaptive urban developments. In fact, water becomes the clockmaker of an integrated, smart system.

Large-scale engineering interventions of the last two centuries often brought negative consequences in terms of flood-protection shifts, water resources management, sustainability, and ecology.[11] Water discharges have led to wider problems in other areas along rivercourses, retention areas in the landscape have been built or removed, embankments have been strengthened with little evaluation of the effects, biotope diversity has dramatically declined because of canalisation. The anthropisation of rivers has generally made the relationship with water harder: water quality is low, playing beside rivers is dangerous due to strong currents, and steep embankments made difficult the access to water paths. To design adaptive

[11] The channelised Los Angeles River, the MOSE Project in Venice, Kissimmee River floodplain dryin out are just few samples of negative actions on the territory.





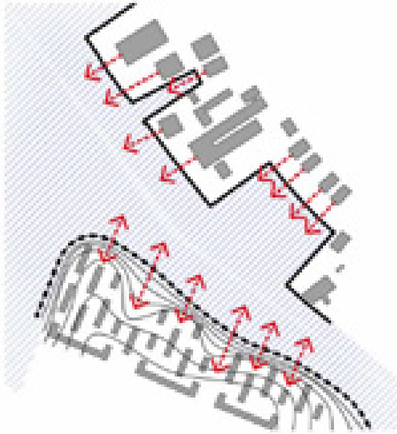
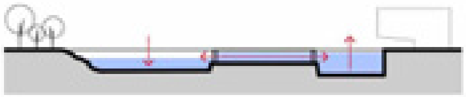


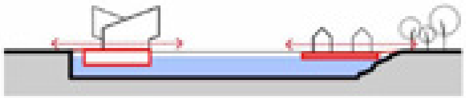
Plate 3.13
Infrastructural strategies to the built environment proposed for the pilot case.

new water paths

canals
- to control water levels in areas with different boundaries' features
- to alterate water speed, varying routes and depths
- to isolate areas designed to be able to absorbe floods

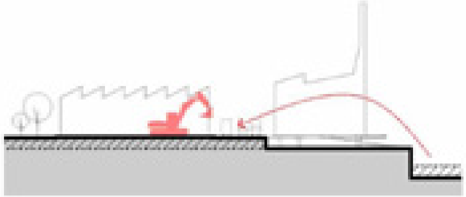


basins
- to absorbe water tides
- to create industrial docks directly connected to industrial sites
- to create embankments and floating areas for fishing and leisure activities



landform variations

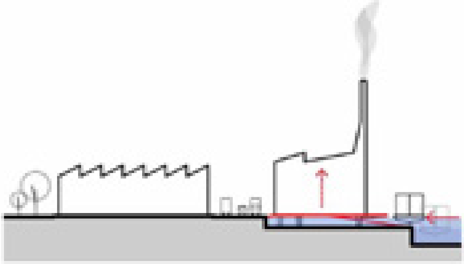
industrial sites
- the soil dug from canals and rivers to lower the riverbed is used to higher the level of industrial sites
- industries and factories are on different levels depending on their relationship with water



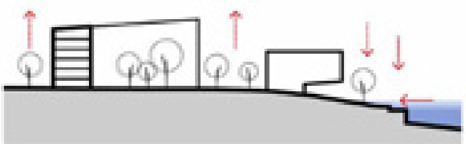
residential areas
- the soil dug from canals and rivers to lower the riverbed and the embankments is used to highten the level of residential sites
- basements designed to be flood for houses close to water

natural and built environment

industrial sites
- industries built on pilework are connected to water path both trough ramps and cantilevered docks
- industries that do not need to be connected to water paths are set on an higher internal level



residential areas
- slopes, green areas and new streets to control water expansion
- flat and green roofs to accumulate and store water and improve drainage systems
- floating houses, cultural and leisure centres within basins or rivers to foster the active use of water paths



infrastructures and flood resistant buildings means to improve the quality of rivers and canals' areas, to raise the quality of the built and the natural environment to communities' needs, and to reduce car dependency. New developments must take into account both water cycle strategies, such as water storage, draining surfaces, waste water treatments, etc., and renewable energy supply network, for instance biomass and wind power.

Having been long undervalued, urban rivers and canals are currently growing as attractive areas in town. A number of stakeholders are involved in the collaborative process: Local Authorities, developers, investors, architects, engineers, and local communities. Because of the multiplicity of actors involved, each single development is a singular challenging opportunity for the city to change its social dynamics. Urban river-scapes are becoming demanded locations, also because of high quality standards of the environment. Waterside living and working places, riverside walkways, port redevelopments, etc. are changing the look of a number of contemporary cities. These relatively new sites are currently requiring new strategies to respond to extremes of weather and flooding. The blueprint can be divided into two strongly dependent categories: infrastructural plans, and structural interventions. Each category gives specific operative guidelines inherent to design process on the main topics of Plates 3.13 and 3.15; these are:

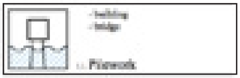
Infrastructural plans:

- Creation of basins, canals, and water corridors to change water flow dynamics;
- Ground level variations to alter water paths' dynamics;
- Increase of tidal lagoons to let water being stored when a flood occurs. (They can also provide daily energy generation, as water can be stored at high tides, and release it at the low ones to activate electric turbines);
- Allow the flooding of public playground and green areas, as in wintertime, when rivers generally flood, these areas are underused;
- Re-naturalisation of riverbed and riverbanks allows more controlled river expansions.

Structural interventions:

- Implementation of permeable surfaces to slow the rain flow towards rivers and canals. Gravel paths and planted swales attenuate rainwater, and disconnect buildings from floodable areas;

Actions from the Guidelines selected for the specific development.



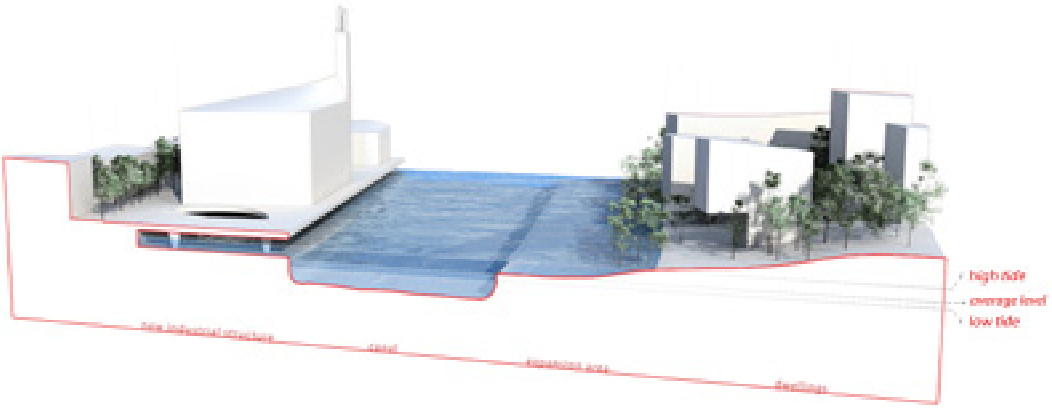


Fig. 3.4
Slice section showing the adaptability of the proposed infra-structure.

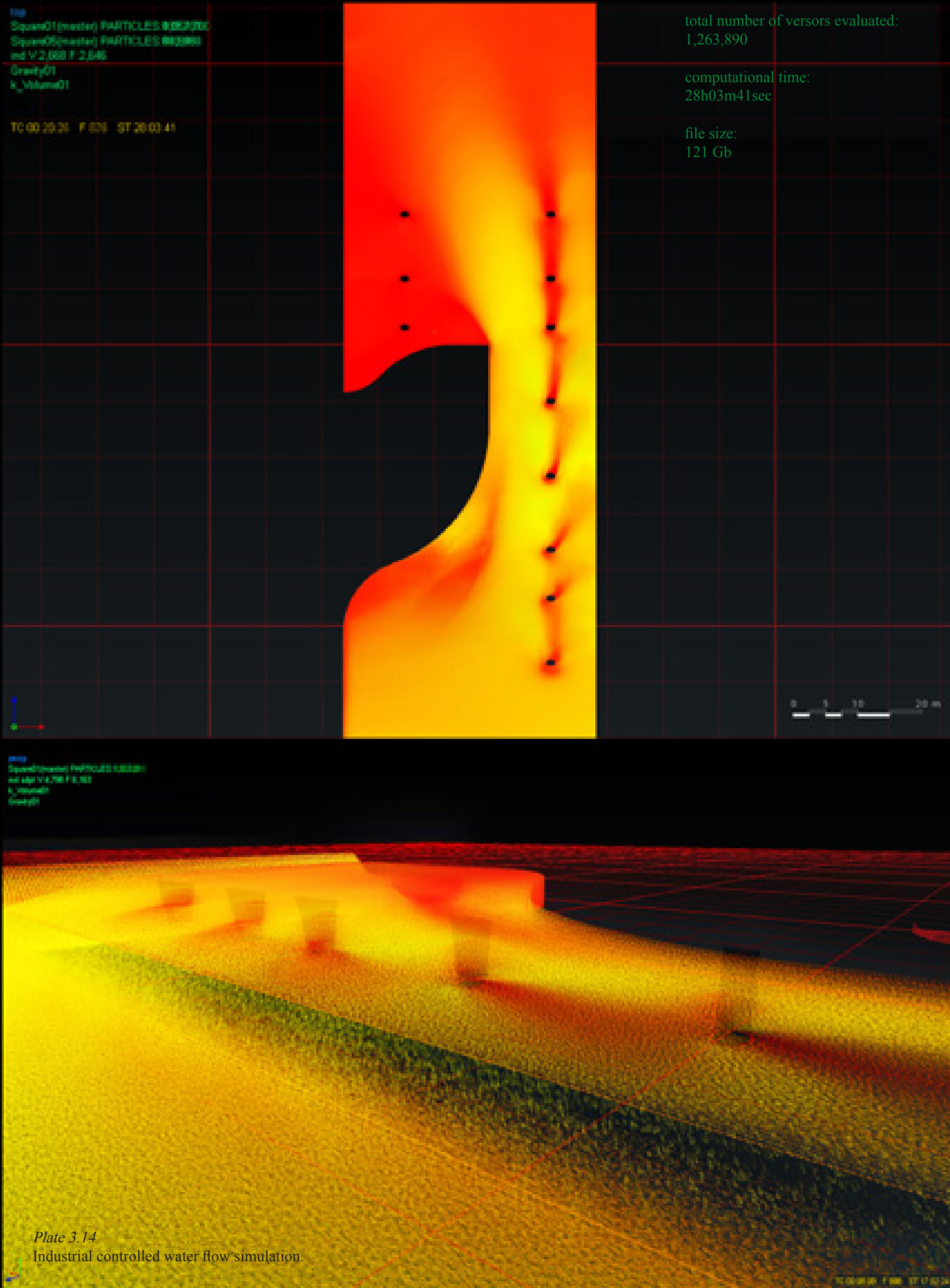
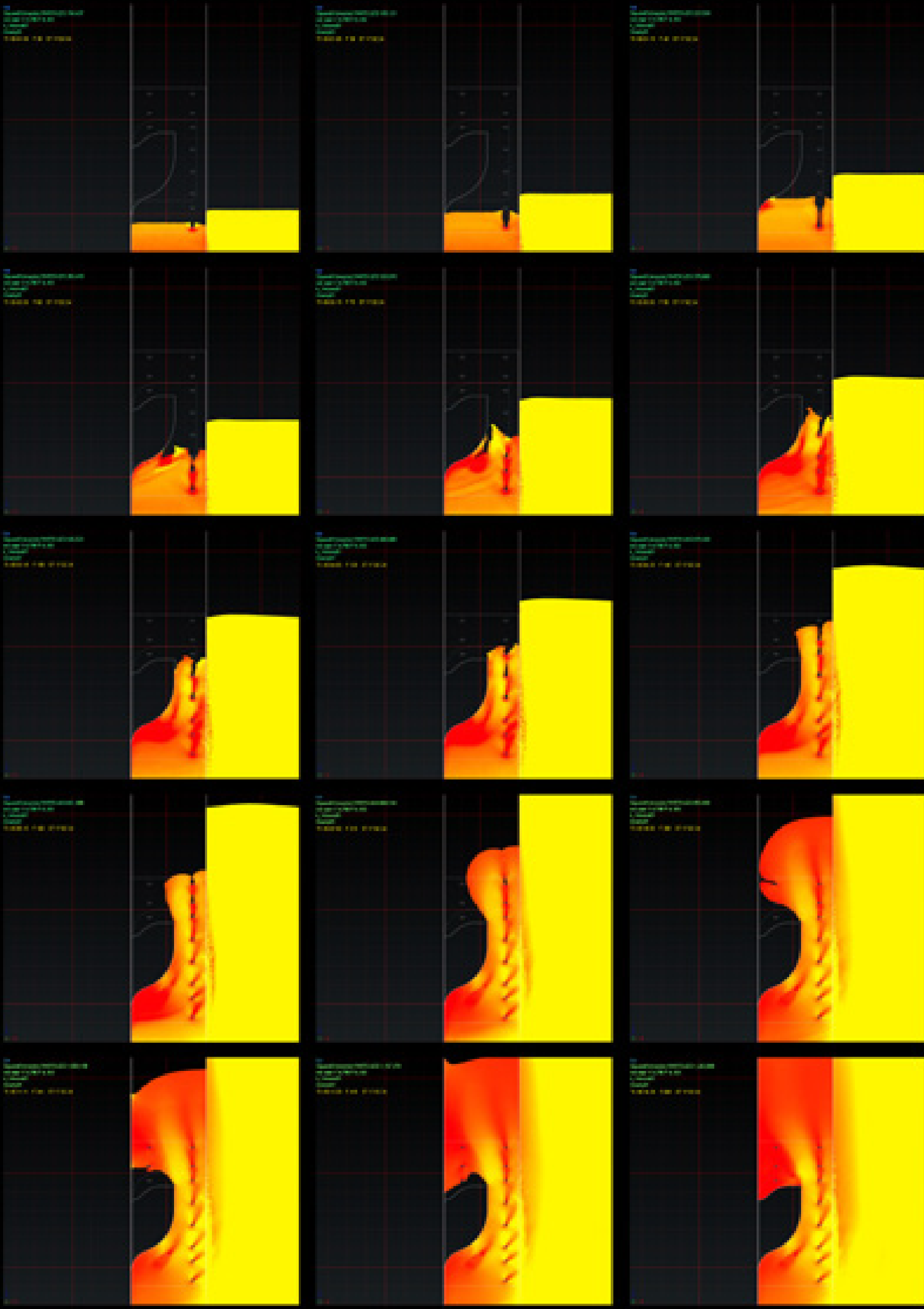


Plate 3.14
Industrial controlled water flow simulation.

FLOW SIMULATION _ palafitte industrial site

the site morphology is adapted in order to take advantage from the river and canal streams



- Construction of communal harvesting system collecting water from public and private amenities, roof gardens, etc.;
- Design of the most appropriate typologies of structures—and generally of buildings—for a specific type of flooding, and the specific level of risk of one area.

The flexibility of the city to come is aimed to create a disaster resilient community in case of floods. It works on two levels: one regards the infrastructures, the other one the structural elements of the city. To be fair, these to layers are the two sides of the same coin, as one would be insufficient without the other. In fact, flexible infrastructures enable changes of the built environment, and alterations of the natural environment over time. In a similar manner, flexible spatial entities demand for infrastructures adaptable to the contingency.

A particularly detailed study is conducted on the pilot case, for the relationship between the River Lee, dwellings, an industrial site, and the inner built environment. As from Plate 3.13, the slice section of Figure 3.4 shows one of the many cases that can be developed. The riverbed is lowered, as well as the riverbanks, and resulting excavated ground is reused right next to the excavation site, in order to create a natural plinth for the dwellings. In doing so, transportation costs are cut, and there is no excess material to move somewhere else. A certain distance, depending on the declivity of the slope, is kept between the riverside and the houses. In this way walking paths and river parks are used as water expansion areas, preventing dwellings to be flooded. Moreover, waterproof basements guarantee an even higher level of security in case of unpredicted extreme events. On the other side of the river, a different approach is taken for the industrial site. It is aimed to the continuous use of the river as trade infrastructure. The industry is settled on two different levels, so that boats shall be able to keep sailing no matter whether the tide is high or low. Creating a double level facing the river, and floating moorings, the flexibility of the built environment affects the infrastructures' adaptability too. The industrial site, i.e. the structural built environment, becomes thus the hinge between two infrastructures, the road on one side, and the river on the other.

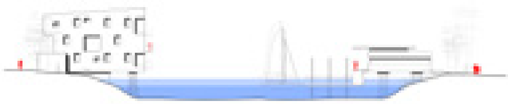
Particular attention is paid to the industrial typology, as flexibility of structures means also different water conditions for a mixed use of the infrastructure. Like a road has parking spaces, acceleration and deceleration lines, and so forth, also a water path must respond to these criteria. This is so, because the mechanic activities, such as loading and unloading operations, are the same on a road, a canal, and a river alike. Starting from a cube, the solid is modelled in order to create faster and slower flows, as it is lifted to join the upper levels. The water studies (Plate 3.14 a, b) on a *Rhinoceros* model are developed on *RealFlow*, as well as the evaluations on the Thames and Lee Rivers in Chapter 3.1.2. These are conducted on an sample of the Lee riverbed, with its average water flow rate. Water speed variations allow for three different configurations. In case of high tide, the lower level is partially or completely submerged, and trade operations work straight from the upper floor. In the mid-tide configuration, the river can be used for different aims in proximity of the industry, and both the two levels can be used. Then, when the tide is low, the functions performed by the upper level can be carried out at the basement level. Naturally, internal layouts must consider the daily phases of working activities, in connection to the daily stages of the local tide.

In 'London as it could be', Sir Richard Rogers started addressing—firstly supported by Lord Michael Heseltine—a series of urban concerns mainly regarding the areas on the Thames, and especially the Docks. [12] His goal was to provide good-quality housing, and improve the aesthetic quality of buildings, convinced that 'architecture should be life-enhancing' (M.Heseltine, 2000). They determinedly supported the idea of reconnect people to the river through the pedestrianisation of the Thames's banks, especially the areas of events site, such as the Somerset House. The road was intended to be converted into a green continuous path, were anyone could walk, rest, and enjoy community's events. All the transport systems were designed to be underground, so that the riverbanks would have been free from danger, and with unpolluted air. In this way, Rogers designed a future social redevelopment before a linear piece of architecture. Moreover, he tried to re-join the artificial and the natural from a different point of view: space, nature, and massing were grouped.

Rivers and canals areas appear to us as both artificial and natural spaces. This was their very nature in the past, as it should be nowadays, since they are the networks of stable communities. They are 'linear ecosystems' (M.Prominski et al., 2009) capable to be adapted on present needs. The role of urban planners is consequently to allow water to be put in relation with new developments, preserving and incrementing resiliency of settlements. Compared to hinterlands and rural area, rivers within conurbation have been reshaped the most by the human hand. Naturally, both rivers' morphology and their dynamics were changed. Hence, the aim of providing guidelines (Plates 3.15, 3.16) is not to restore rivers to their natural

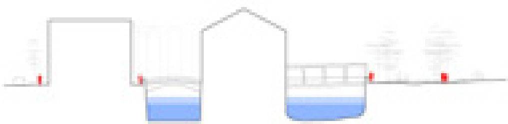
[12] Richard Rogers Partnership, 1986, *London As It Could Be*, design, Embankment, London.

	1. Avoiding	2. Adapting	3. Allowing
BUILT ENVIRONMENT	- building - bridge 1.1. Pilework	- dike dwelling - basement as shops - basement as car park - water tight double entrance 2.1. Flood-tolerant structures	- city wall - fold-out protection - watertight façade 3.1. Steady resistance
	- terp dwelling 1.2. Mound	- floating path - floating building - amphibious building 2.2. Flood-adaptive structures	Allowing
	- bulding - land 1.3. Suspended pathway	Adapting	Allowing
LAND	- dike - dike park 1.4. Natural embankment	Adapting	- submergible pathway - lagoon - playground - sports facilities 3.2. Controlled flood
	- wall - bags 1.5. Temporary resistance	Adapting	Allowing
	- riverside heighten - ploodplain reprofiling - dike resetting 1.6. Landform variation	Adapting	Allowing
WATER PATHS	- water path widening - water path deepening - flow length extension 1.7. Excavation	- balcony - terrace - steps - runway 2.3. Flexible embankment	- harbour - tidal lagoon - river access 3.3. Water expansion basin
	- riverbed variation - bank variation - groyne (revetment) 1.8. Alteration	- riverbank renaturalisation - sand or gravel beach in bay 2.4. Flexible landform	- river to artificial lake - branch - stream corridor 3.4. Connective canal
	- stabilisation wall - embankment strengthen 1.9. Reinforcement	Adapting	Allowing

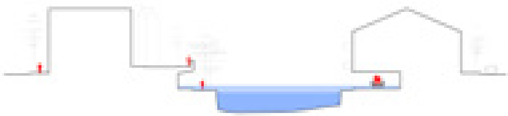


1.1

1.2



1.3



2.1

2.2

3.1

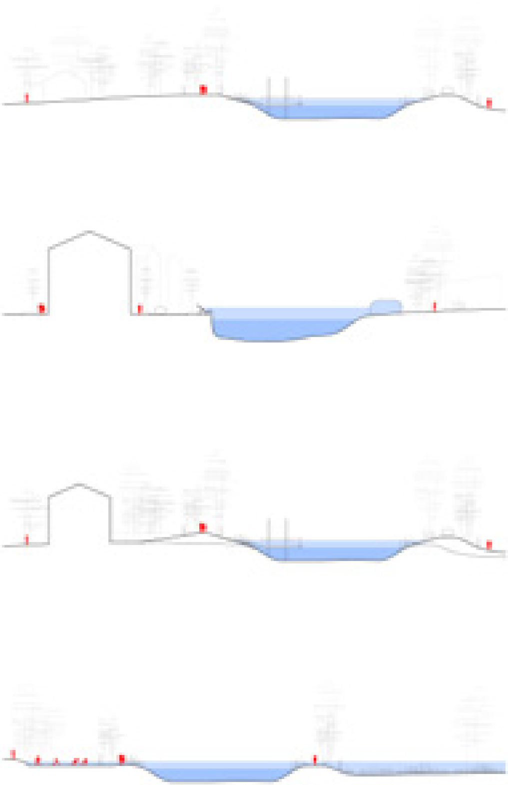
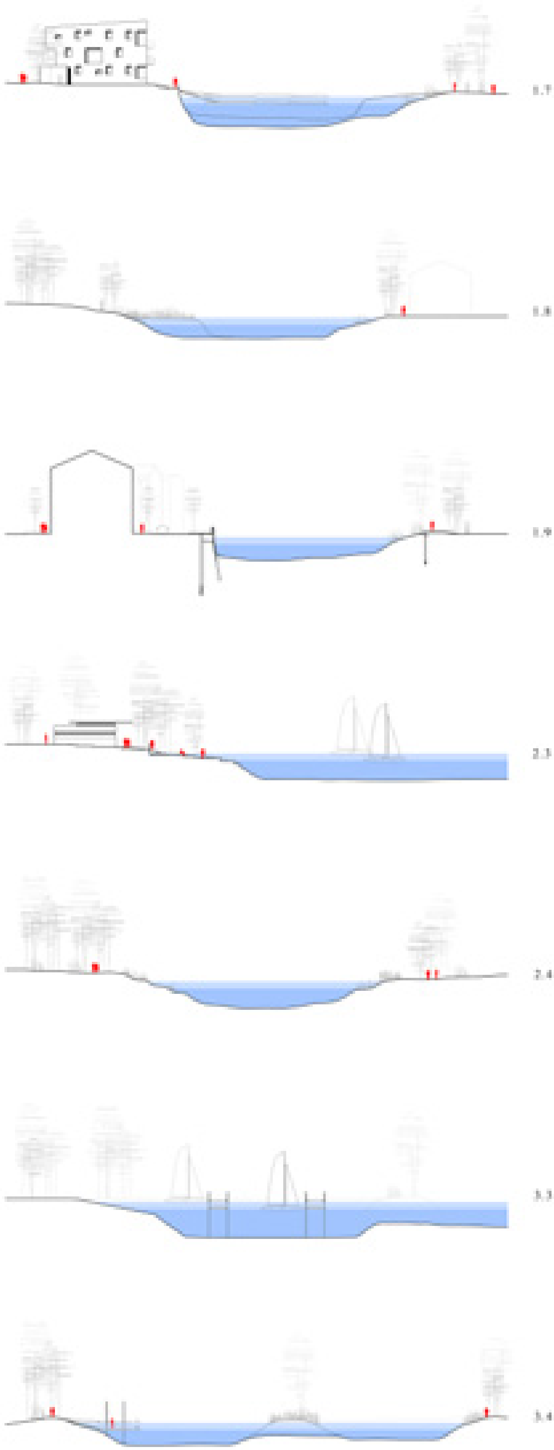


Plate 3.15, p. 220
Guidelines for territory planning.

Plate 3.16 (a, b, c), pp. 221-223
Territorial sections for the categories ‘built environment’, ‘land’, and ‘water paths’.



condition—because it is clearly impossible—but to give right answers to planning issues. Concordant with the telematic map of the risk, they shall create new synergies between water spaces and people's behaviour, connecting natural phenomena, civil engineering systems, and landscape design. The aim of the *Telematic Map of Risk* is to systematise flood resilient design strategies for possible areas of development, responding to the challenges of global warming. Three are the strategies proposed: *avoiding*, *adapting*, and *allowing*—which refers to the relationship that actions establish between water and spatial entities.

The first approach to planning is to *avoid* built and environmental entities being involved in water dynamics. The built environment can be 'lifted' through pile works or mound, so that human activities can keep going having not direct relationship to water. Also bridges above floodable areas may be built for the same aim. Land can be protected to flooding as well by steady or temporary devices: natural embankment can be raised, and landform can be controlled. The banks can be varied both in height and width, re-profiling the entire floodplain, resetting dikes, and improving riversides. Riverbed can be altered varying its dimensions or changing its morphology so that water flows undergo adaptive changes. Moreover, embankment may be reinforced and stabilised when a fixed built environment does not allow any flexibility within its fabric.

Water paths and the built environment can be reformed in order to prosper from their adaptation to water dynamics. Buildings characterised by flood-tolerant or -adaptive structures become the core of the strategy based on infrastructural flexibility. In fact, the capacity of the built environment of floating or being partially flooded shifts the design process onto a higher layer of *adaptation*. While it is not possible to create adapting land, as one area does undergo a flood or does not, water paths are interesting adaptive system to work on. Indeed, both embankments and the natural banks can be redesigned to be completely or partially flooded land. They guarantee different human activities connected to the river and canal bank experiences.

A third approach is to *allow* water to take possession of the territory. Specifically, the built environment can be reinforced, and watertight façade can be developed, in order to be a boundary for water. Lagoons and playground can be connected to river and canals, allowing controlled flooding. Water expansion basins are highly important in order to mitigate catastrophic changes of water level and water flows.

New synergies between people and the water are enhanced by the fact that all these interventions are not acupunctural ideas to apply random on the territory. First of all, they depend on the level of risk (see spatial features on Annex A). For instance, to intervene on an area considered at risk R4-5 with floating houses would be wrong, as the level of water would be suitable for that intervention in a 100 year time. So, each spatial feature is associated with a certain range of risk level. Secondly, they cannot be individual spots, because they need to be put in connection with other interventions. In fact, the distinction between actions on the built environment, the land, and water paths means that the interventions shall be used as a global strategy, involving the territory as a whole. The guidelines are aimed to connect different areas of the city characterised by similar features and similar levels of risk. Furthermore, they are network by themselves, establishing a web of complementary actions. The effort to work only within a specific spatial entity category would be vain. To work on a new development, or to redevelop a brownfield area does not only mean to build new blocks and to plant new trees, after having elaborated a disaster-resilient strategy for future:

> "[w]e must develop an intervention directed by the complicated factors of two great components in perpetual interaction: the material setting of life and the behaviours that it incites [... The] prospects for action on the environment lead, in their latest development, to the idea of unitary urbanism. Unitary urbanism first becomes clear in the use of the whole of arts and techniques as means cooperating in an integral composition of the environment."[13]

Efficient developments in Flood Warning and Alert Areas are possible. Overall non-defensive strategies are the keystone of adaptive systems trying to contrast flood risk. Increasing construction costs by about 1-2% (BACA, 2009) for water risk management, greater saves can be made in disaster operations. "Broad-scale estimates made shortly after the [2007] floods put the total losses at about £4 billion, of which insurable losses were reported to be about £3 billion."[14] There is no a unique way to tackle flood risk management in a development area: various can be both the approaches and the solutions to a series of cases.

For this reason, the diagram of Figure 3.5 shows all the possible combination between single actions to take. The colours of the swept circle

[13] Debord, G.E., 2006 (1957), "Report on the Construction of Situations". In *Situationist International Anthology* (translated by Ken Knabb), Bureau of Public Secrets, Berkeley, p. 44.

[14] Environment Agency, 2010, *Delivering benefits through evidence. The costs of the summer 2007 floods in England*, Environment Agency, Bristol.

represent the built environment (red), the land (green), and water paths (blue), and the black marks below (one to three) indicate the relationship between water and spatial entities—avoiding (one), adapting (two), and allowing (three). Every action, from 1.1 to 3.4, can create more than one triangulation with spatial entities of another category (built environment, land, and water paths). Hence, each action can affect the territory in tight connection to other adaptation systems. For example, designing flood-adaptive structures (from the category 'built environment') entail to work on the land through (a) landform variations and (b) areas for controlled flood. On their turn, each one of these is connected to other possible actions on water paths.

Prevention aimed to a flood-resilient community can be reached only through simultaneous actions on the three categories. Again, it is a matter of space and time: to leave the built environment, the land, and water paths disconnected would mean to nullify the operation itself, and economic outlays too.

Notes

[12] The *Rapport sur la construction des situations et sur les conditions de l'organisation et de l'action de la tendance situationniste internationale*, Paris, 1957, was one of the preparatory texts for the July 1957 conference at Cosio d'Arroscia, Italy, at which the Situationist International was founded.

> *Nous ne devons pas refuser la culture moderne, mais nous en emparer, pour la nier. Il ne peut y avoir d'Intellectuel révolutionnaire s'il ne reconnaît, la révolution culturelle devant laquelle nous nous trouvons. Un intellectuel créateur ne peut être révolutionnaire en soutenant simplement la politique d'un parti, serait-ce par des moyens originaux, mais bien en travaillant, au côté des partis, au changement nécessaire de toutes les superstructures culturelles. De même, ce qui déter-mine en dernier ressort la qualité d'intellectuel bourgeois, ce n'est ni l'origine sociale, ni la connaissance d'une culture—point de départ commun de la critique et de la création—, c'est un rôle dans la production îles formes historiquement bourgeoises de la culture. Les auteurs à opinions politiques révolutionnaires, quand la critique littéraire bourgeoise les félicite, devraient chercher quelles tantes ils ont commises.*

(Debord G.E., 1957, *Rapport sur la construction des situations*, Paris, p.VII)

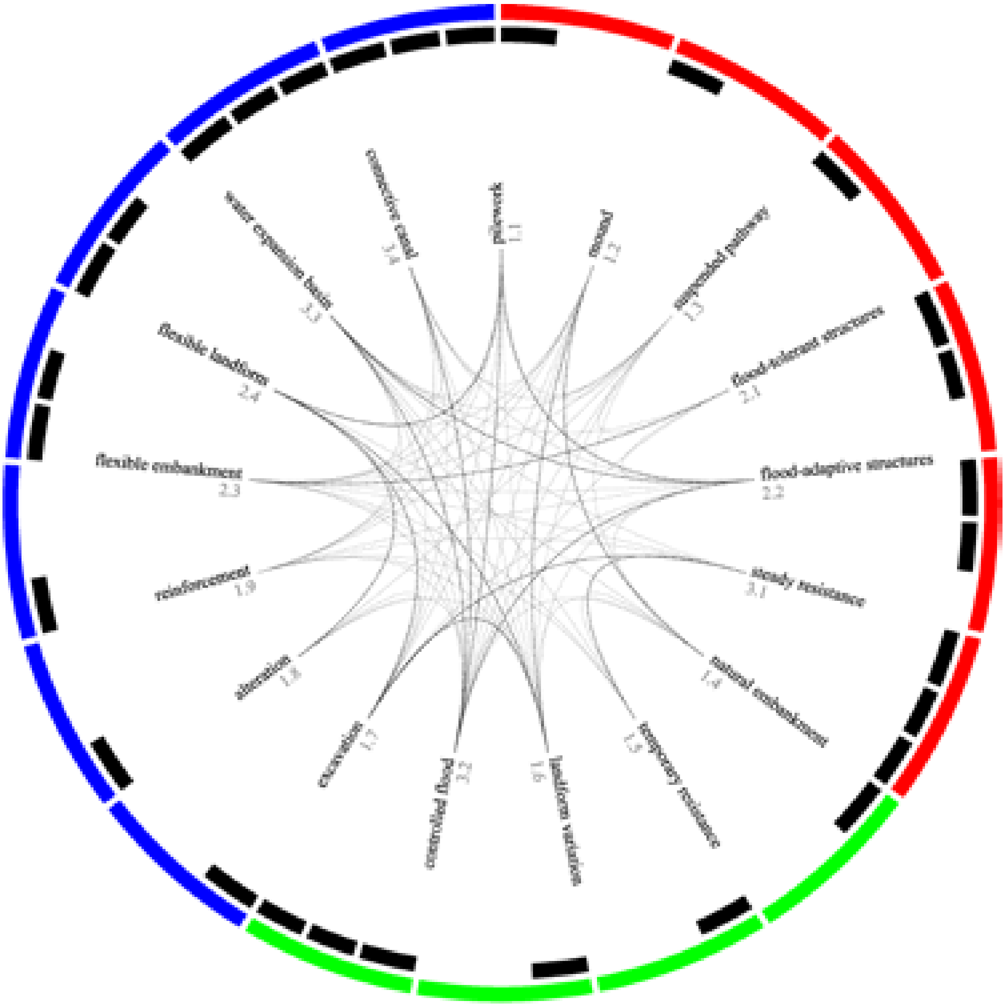


Fig. 3.5
Spatial entities' possible relationships.

ANNEX A

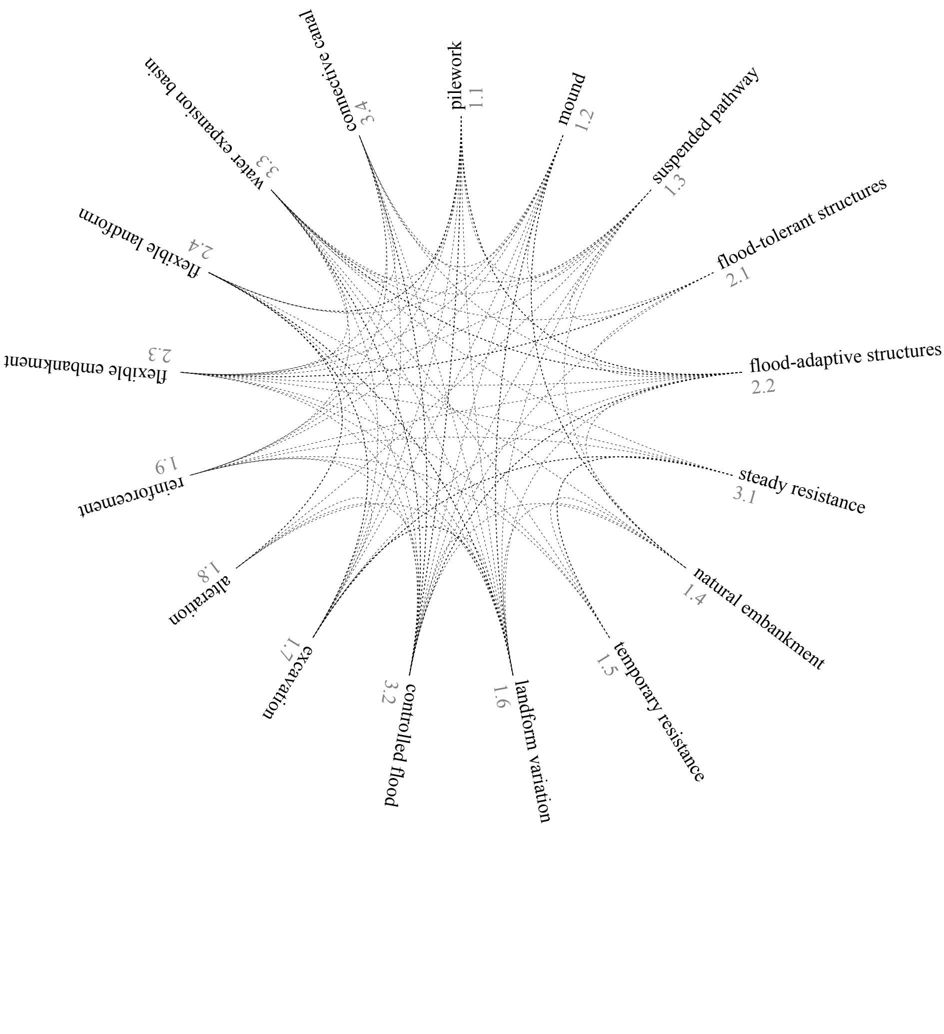
Guidelines

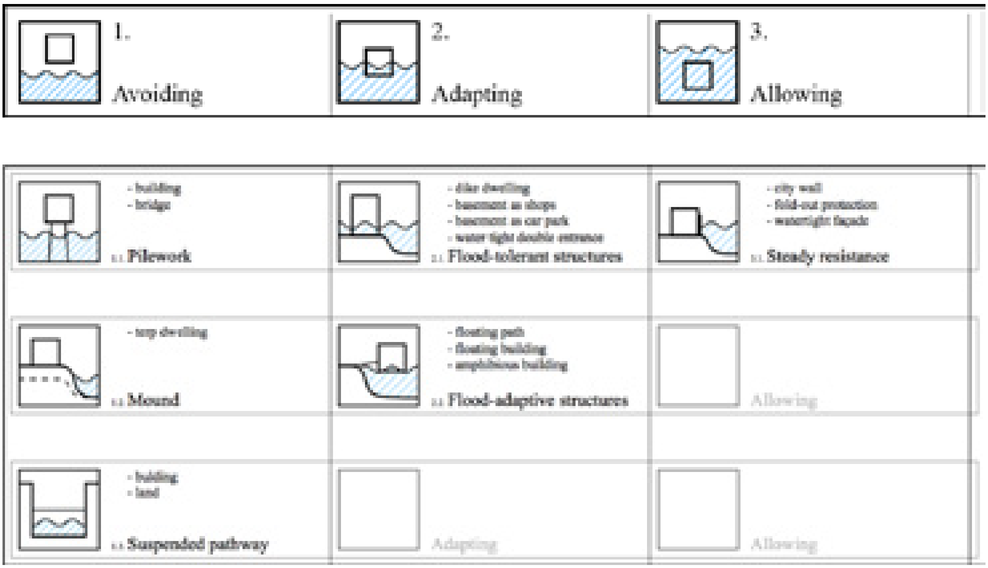
The aim of this first appendix is to provide a detailed spectrum of design approaches, and innovative built examples of flood-related preventive interventions. As explained in chapter ***3.2.2. (Guidelines for territory planning)***, the design strategies shows some example of responding to rivers' needs, and people's necessities. They illustrate attitudes the designers should adopt towards water management, through the reading of outcomes of the ***telematic map of the risk***. The three different approaches, i.e. to *avoid* (1.), to *adapt* (2.), and to *allow* (3.) water being in relationship with spatial entities, will be analysed for each spatial category: the built environment, the land, and water paths.

Every single criterion covers all the spatial features of the guidelines, that must be combined in order to better respond to socio-territorial demands. It is indeed quite unlikely the chance to resolve an urban issue simply through one unique design tool. As shown in the ***cluster plan***, each design intervention has a series of recommended combinations with design tools from the same category, or from others. For instance, *flood-adaptive structures* (2.2) as *floating buildings*, from the criterion 'adaptation', spatial entity 'built environment', can be combined with *controlled flood* areas (3.2) as *lagoon*, from the criterion 'allowing', spatial entity 'land'; or with *water expansion basins* (3.3) as *harbours*, from the criterion 'allowing', spatial entity 'water paths.'

The guidelines are an open scheme, susceptible to extentions and reviews, as thechologies advance.

	1. Avoiding	2. Adapting	3. Allowing
BUILT ENVIRONMENT	1.1. Pilework - building - bridge	2.1. Flood-tolerant structures - dike dwelling - basement as shops - basement as car park - water tight double entrance	3.1. Steady resistance - city wall - fold-out protection - watertight façade
	1.2. Mound - terp dwelling	2.2. Flood-adaptive structures - floating path - floating building - amphibious building	Allowing
	1.3. Suspended pathway - bulding - land	Adapting	Allowing
LAND	1.4. Natural embankment - dike - dike park	Adapting	3.2. Controlled flood - submergible pathway - lagoon - playground - sports facilities
	1.5. Temporary resistance - wall - bags	Adapting	Allowing
	1.6. Landform variation - riverside heighten - ploodplain reprofiling - dike resetting	Adapting	Allowing
WATER PATHS	1.7. Excavation - water path widening - water path deepening - flow length extension	2.3. Flexible embankment - balcony - terrace - steps - runway	3.3. Water expansion basin - harbour - tidal lagoon - river access
	1.8. Alteration - riverbed variation - bank variation - groyne (revetment)	2.4. Flexible landform - riverbank renaturalisation - sand or gravel beach in bay	3.4. Connective canal - river to artificial lake - branch - stream corridor
	1.9. Reinforcement - stabilisation wall - embankment strengthen	Adapting	Allowing


pilework
1.1
mound
1.2
suspended pathway
1.3
flood-tolerant structures
2.1
flood-adaptive structures
2.2
steady resistance
3.1
natural embankment
1.4
temporary resistance
1.5
landform variation
1.6
controlled flood
3.2
excavation
1.7
alteration
1.8
reinforcement
1.9
flexible embankment
2.3
flexible landform
2.4
water expansion basin
3.3
connective canal
3.4

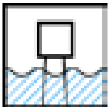

1.
Avoiding
2.
Adapting
3.
Allowing
- building
- bridge
Pilework
- dike dwelling
- basement as shops
- basement as car park
- water tight double entrance
Flood-tolerant structures
- city wall
- fold-out protection
- watertight façade
Steady resistance
- terp dwelling
Mound
- floating path
- floating building
- amphibious building
Flood-adaptive structures
Allowing
- building
- land
Suspended pathway
Adapting
Allowing

Built environment

Avoiding:
- Pilework
- Mound
- Suspended pathway

Adapting:
- Flood-tolerant structures
- Flood-adaptive structures

Allowing:
- Steady resistance



Pilework

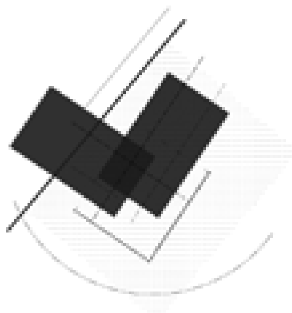
Piles protect the main bodies of dwellings from floods, as the floodwaters can flow underneath them. Also the discharge is not impeded, since structural elements on the ground are just pilotis or thin concrete slabs. Buildings, plaftorms and bridges on stilts are always connected to the ground—on different heights—by stairs and ramps, and to water by floating platforms. To flood the area underneath and beside a building on piles allows for the continuation of the activities within the building. The use of the paths below water level is partially or totally suspended, and replaced by other complementary activities.

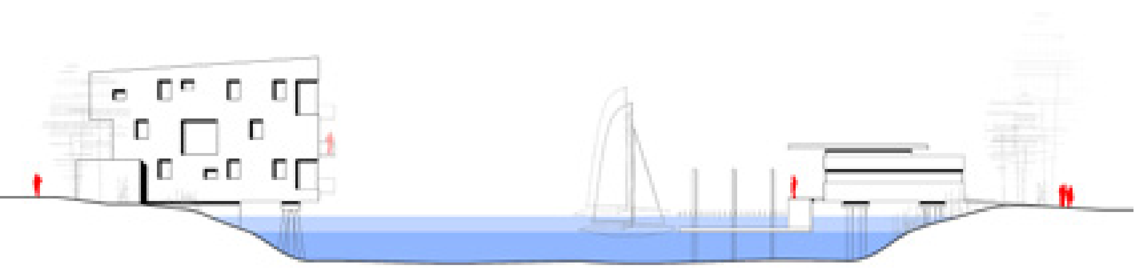
Spatial quality

Pilework performs properly from flood risk level R2 to R5.

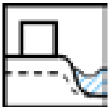
It works ideally in collaboration with flood-adaptive structures, controlled flood systems, and flexible landform. Other associated operations can be suspended pathway, landform variation, excavation, reinforcement, flexible environment, and water expansion basin. Pileworks can form a peninsula or be totally surrounded by water.

Innovation in technology mainly regards the connection to the building, and the integration of building installations.





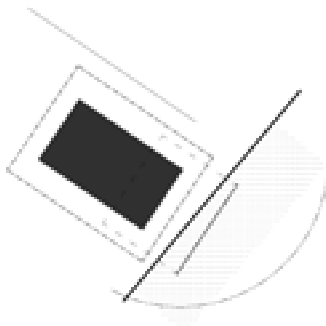
A. Silodam, MVRDV - Amsterdam (NL), 1995-2003
B. Bicycle Snake, DISSING+WEITLING Architecture - København (DK), 2014
C. Farnsworth House, L.M.van der Rohe - Plano (USA), 1951

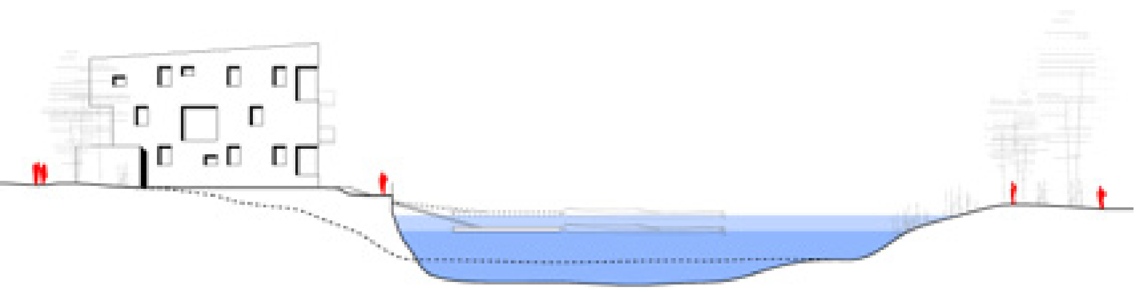


Mound

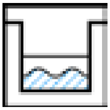
The oldest human settlements close to water courses and the sea were located on higher ground. Mound allows for the submersion of part of the floodplaind (usually farmland) and the preservation of the built environment. Both natural and man-made mounds remains accessible during flood events through dike systems. Mounds are usually made of a sand core coated by a thick layer of clayey soil planted with grass, as well as dikes.

Spatial quality
Mound performs properly from flood risk level R2 to R5.
It works ideally in collaboration with natural embankment, landform variation, and controlled flood areas. Other associated operations can be excavation, reinforcement, flexible landform and embankment, and water expansion basin. Mounds are totally surrounded by water in case of flood.
Technological innovation specifically concerns the way polders are flooded, breaking the ground belt formed by mounds and dikes.





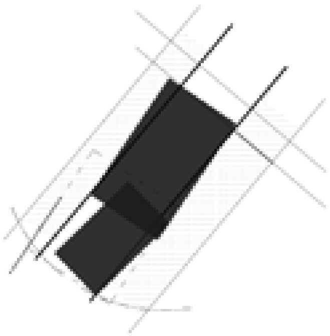
A. Holzhafen West, KCAP / ASTOC - Hamburg (DE), 2009-2011
B. Knudtwarft dwelling - Hallig Suedfall (DE), 1741
C. Church and bell tower - Ezinge (NL), 13th century

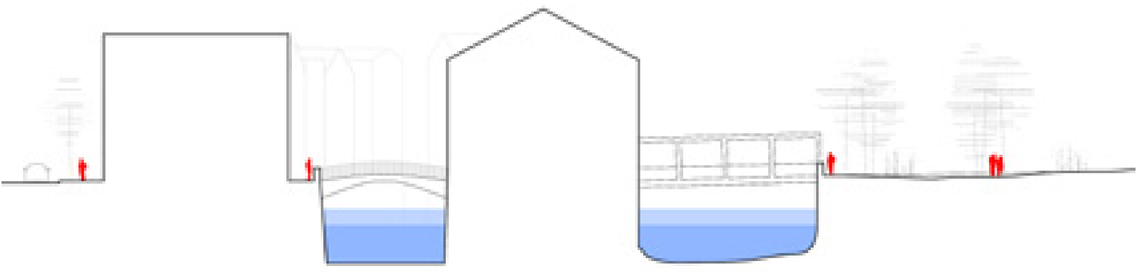


Suspended pathway

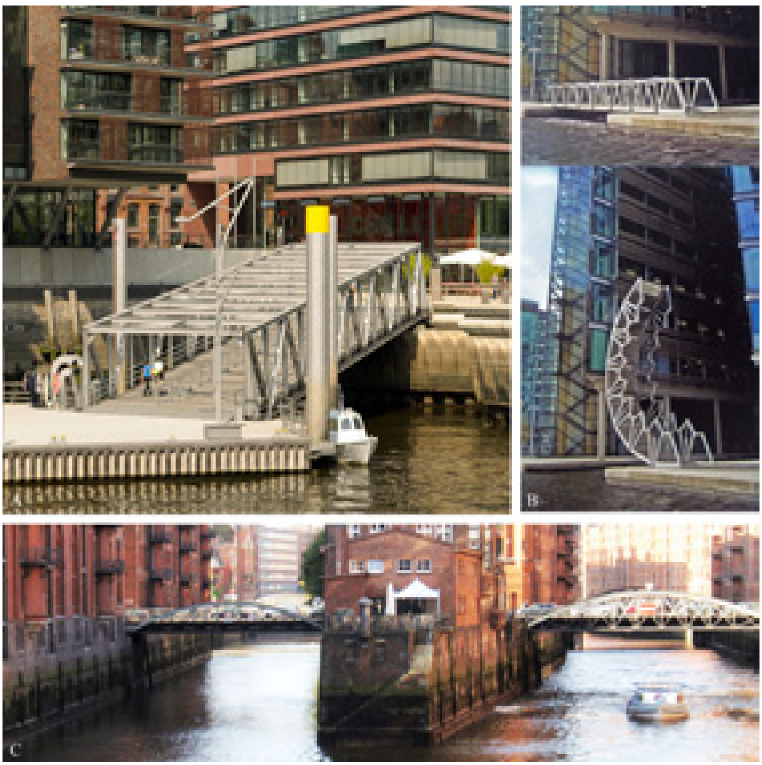
To live public and private space, and guarantee escape routes even during extreme high water conditions, new housing developments, playgrounds, and squares can employ entire access systems that lays above the floodwater. Bridges allow for the connection of areas on the same or different levels in safety condition. Suspended pathways can be pedestrian paths, cycle tracks, roads, highways, railways, and water bridges.

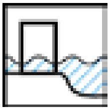
Spatial quality
Suspended pathway performs from flood risk level R1 to R5.
It works ideally in collaboration with pilework, flood-tolerant and flood-adaptive structures, reinforcement and connective canals. Other associated operations can be mound, natural embankment, landform variation, controlled flood, alteration, flexible embankment, and water expansion basin. Suspended pathways are always above water in case of flood.
Technological innovation specifically concerns shape and section optimisations to reduce the use of materials and increase the span lenght.





A. Bridge on a dock in HafenCity, KCAP *(master plan)* - Hamburg (DE), 2003
B. Rolling Bridge, Heatherwick studio - London (UK), 2004-2005
C. Bridges on the canals - Hamburg (DE)





Flood-tolerant structures

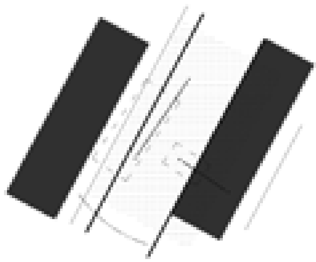
Appropriate flood-tolerant structures can be subjected to flooding without sustainig any damage. Tolerant attitude to floods shall reduce the costs and efforts to protect buildings via external strategies disjointed to the building design and construction phases. Buildings can be integrated in mounds, or having basement acting as mound in itself. The base storey usually houses car parks, shops and cafés. During floods basements can be sealed off and made water-proof through fold-out protection shutters. Walls and floors are ideally tiled, and electrical installations must be protected.

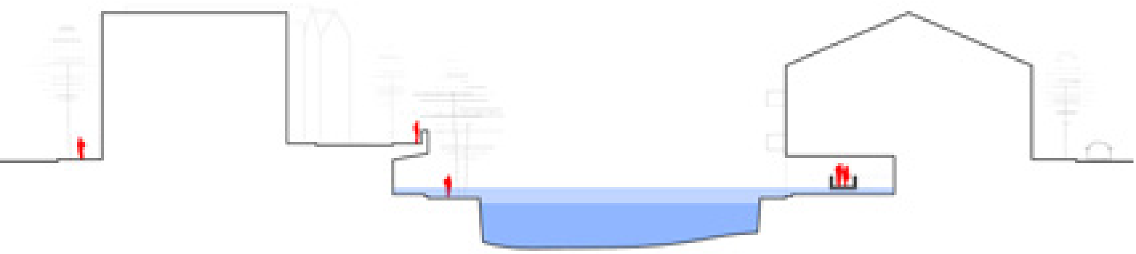
Spatial quality

Flood-tolerant structures perform properly from flood risk level R1 to R2.

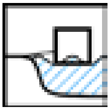
They work ideally in collaboration with flexible embankments and reinforce. Other associated operations can be suspended pathway, water expansion basin, and connective canal. Flood-tolerant structures can be in total or partial contact with water, depending on the block they are in.

Innovation in technology mainly regards protection shutters and the way these stuctures are integrated in city centres protected by National Trust.





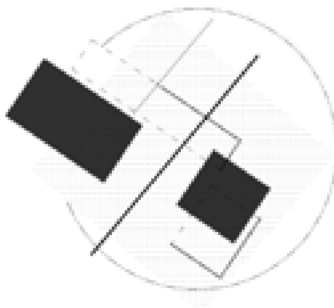
A. Palazzo Querini Stampalia (restoration), Carlo Scarpa - Venice (IT), 1961
B. Campiello de la Scuola - Venice (IT)
C. Palazzo Querini Stampalia (restoration), Carlo Scarpa - Venice (IT), 1961

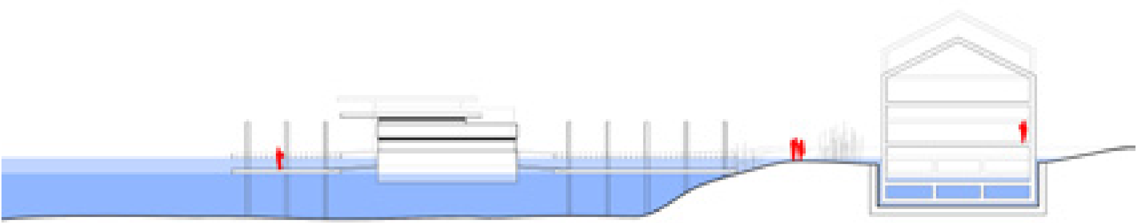


Flood-adaptive structures

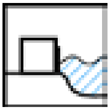
Floating buildings and platforms rise with the flood-waters. Particularly used for residential developments in floodplains and on water, and jetties, flood-adaptive structures are moored to steel pylons (floating structures) or accomodated in concrete tanks (amphibious houses). Usually the first typology allows for a higher float-up, since amphibious buildings can raise no more than the basement height. Floating structures have very little effect on the retention capacity of one site, and can be broadly applied to whole new developments.

Spatial quality
Floating structures perform from flood risk level R1 to R5; amphibious houses from R1 to R4.
They work ideally in collaboration with controlled flood areas, water expansion basins, pilework, and suspended pathway. Other associated operations can be natural embankment, landform variation, excavation, reinforcement, flexible embankment, and connective canal. Flood-adaptive structures have their ground level always above water level.
Technological innovation specifically concerns morphological aspects, building construction systems, and the integration of building installations.





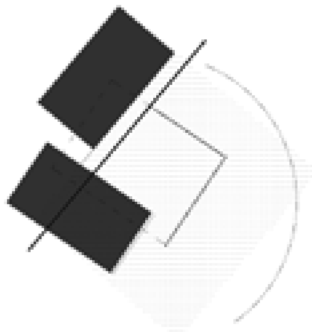
A. Makoko Floating School, NLE Architects - Lagos (NG), 2012-2013
B. Floating houses in IJburg, Architectenbureau Marlies Rohmer - Amsterdam (NL), 2001-2011
C. Amphibious house, Baca Architects - Marlow (UK), 2013-2014

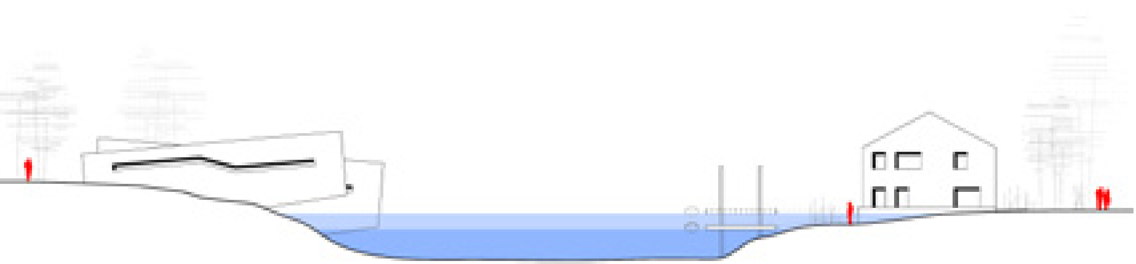


Steady resistance

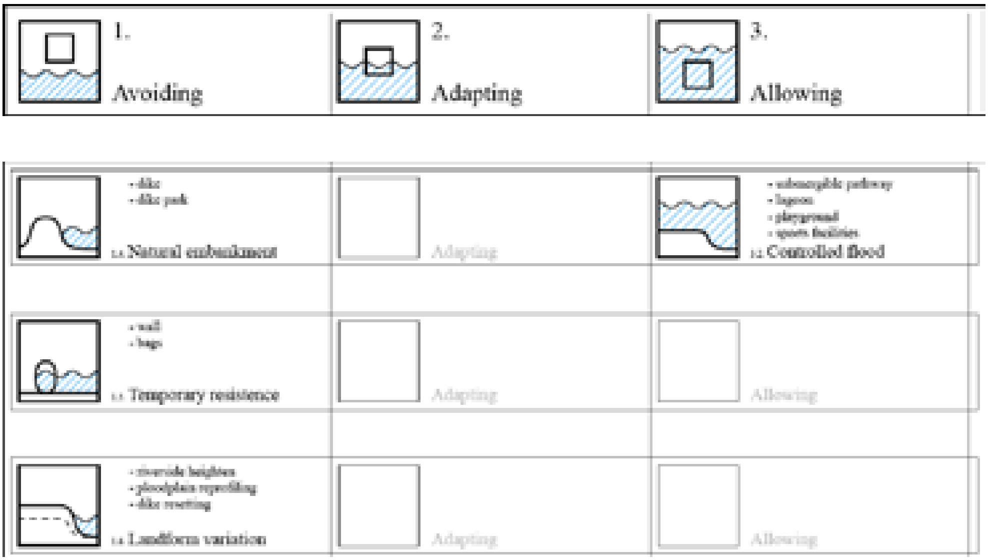
Compact built environments and city centres' flood protection systems can be reinforced or raised in response to the increased likelihood of flood events. Existing structures are converted and stabilised in synergy with National Trust, so that water is not a threat anymore for historic heritage. The height of existing wall can be raised accordingly with bridges and locks. Existing fronts can be converted into flood-resistant facades, and doors and windows replaced with safety glasses and frames. Fortification can be utilised for flood protection, after having improved their stability and being sealed.

Spatial quality
Steady resistance performs properly from flood risk level R1 to R4.
They work ideally in collaboration with excavation and reinforcement, and with temporary resistence in case of extraordinariness. Other associated operations can be flexible embankment, and water expansion basin. Steady resistance structures are always in contact with water on one side, during flood events. Technological innovation specifically concerns, building construction and protection systems, and waterproofing techniques.





A. City wall - Wörth am Main (DE), 2001
B. Presray FB77, Texas Medical Center - Houston (USA)
C. The Dryline *(federal competition)*, BIG / One Architecture - New York City (USA), 2014-2015


1.
Avoiding
2.
Adapting
3.
Allowing
Natural embankment
Adapting
Controlled flood
Temporary resistence
Adapting
Allowing
Landform variation
Adapting
Allowing

Land

Avoiding:

Natural embankment
Temporary resistence
Landform variation

Adapting:

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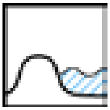
Allowing:

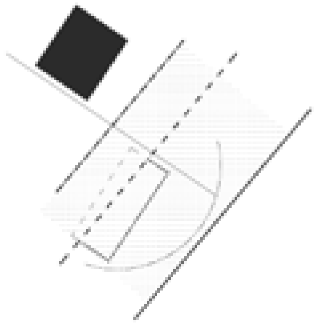
Controlled flood

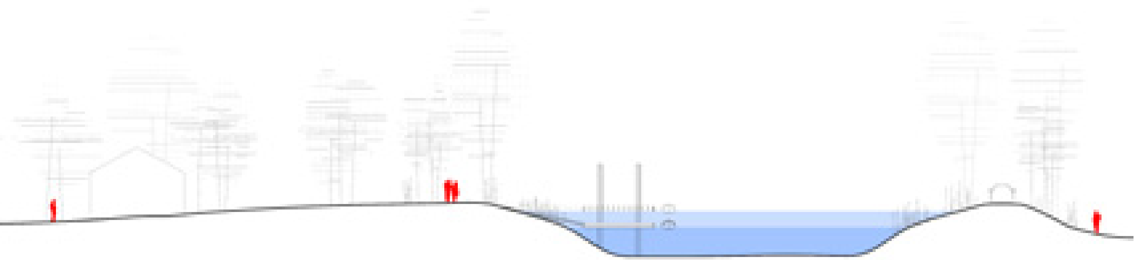


Natural embankment

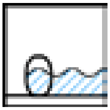
When the landscape provide enough space, linear systems for flood protection is usually represented by dikes i.e., natural embankment. The trapezoid cross-sections of dikes is crucial for their function. Re-profiling the shape of dikes can create new spatial arrangements ho enhance their use potentials, in terms of trees plantation (to consolidate and stabilise ground), cycle and pedestrian paths, and small infrastructures. The flatter the dike, the more stable and less perceptible. Dikes can always be reinforced integrating sheet piling walls within the dike construction.

Spatial quality
Natural embankment performs properly from flood risk level R1 to R4.
It works ideally in collaboration with mound, and controlled flood areas. Other associated operations can be suspended pathway, flood-adaptive structures, temporary resistance, landform variation, and flexible landform and embankment. Natural embankments are linear infrastructures facing water on one side.
Technological innovation specifically concerns the way polders are flooded, breaking the ground belt formed by mounds and dikes.





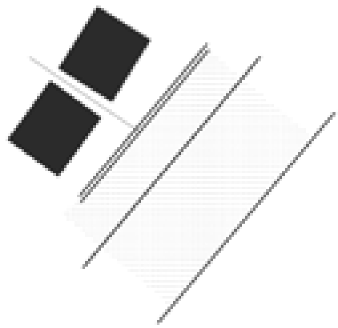
A. Dike on the North Sea (NL)
B. Dike between Chiawana Park and Wade Park - Pasco (USA)
C. Dike - Uitdam (NL)

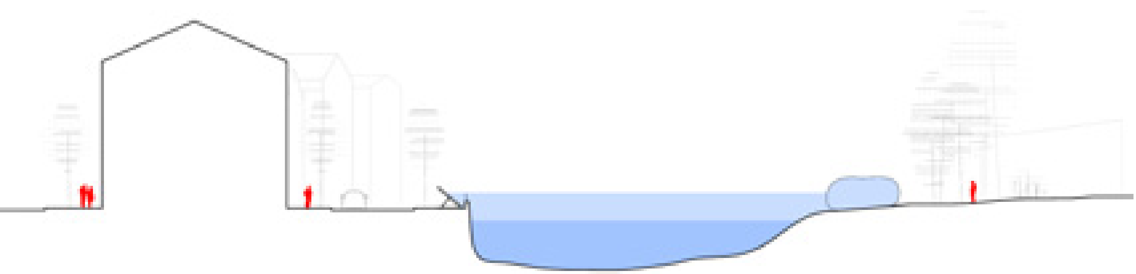


Temporary resistance

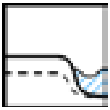
Temporary defences can close gaps in continuous structures or raise the flood protection as water rises. Portable (no framework needed) and attachable protection elements can replace or supplement permanent resistance. During normal flows and low water conditions they are removed and stored in depots. Fold-out protection elements shut openings in defence walls, dikes and buildings. They can be manual, automatic, or electronic devices. Studies concerning water loads are crucial for building temporary resistance.

Spatial quality
Temporary resistance performs properly from flood risk level R1 to R3.
It is associated to interventions such as reinforce, natural embankment, reinforcement, flaxible landform and embankment, and water expansion basin. Temporary resistance structures are always in contact with water on one side, during flood events.
Innovation in technology mainly regards engineering solutions concerning new materials, and ways to use floodwater as barrier itself when collected into inflatable plastic bags.





A. Temporary barrier on the River Severn - Ironbridge (UK)
B. FloodFender, water-inflated temporary dam
C. Temporary barrier on the River Camlin - Longford (IE)



Landform variation

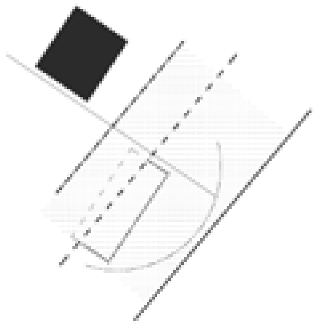
Design approach to landscape is aimed to provide better flood-protection through soil movements, creating a various multi-funcitional limit to water. Boundaries are thus not lines but thick areas where many activities take place. Embankments, levees and dikes' sections can be perfectioned and better connected to adjacent natural and built environment using soil extracted from close sites, such as ditches, working sites, and river excavation. Particular attention must be given to spatial quality of interventions, as these are in tight relation to consolidated cityscapes and sensitive ecosystems.

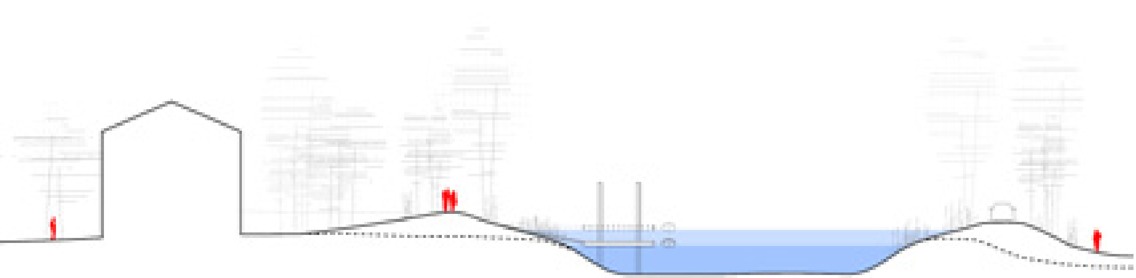
Spatial quality

Landform variation performs properly from flood risk level R2 to R5.

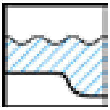
It works ideally in collaboration with excavation, flexible landform, and mound. Other associated operations can be suspended pathway, flood-adaptive structures, alteration, reinforcement, flexible embankment, water expansion basin, and connective canal. Landform variation is a linear infrastructure facing water on one side.

Innovation specifically concerns the preservation of balanced ecosystem.





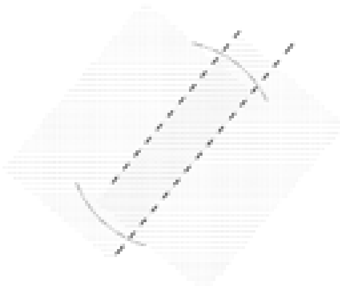
A. Parque del Agua L.Buñuel, Alday Jover Arquitectos / L'Atelier de Paisaje - Zaragoza (ES), 2008
B. Müngsten Bridge Park, Atelier Loidl Landschaftsarchitekten - Müngsten (DE), 2006
C. Gamerense Waard Floodplain Renaturation - Gameren (NL), 1999

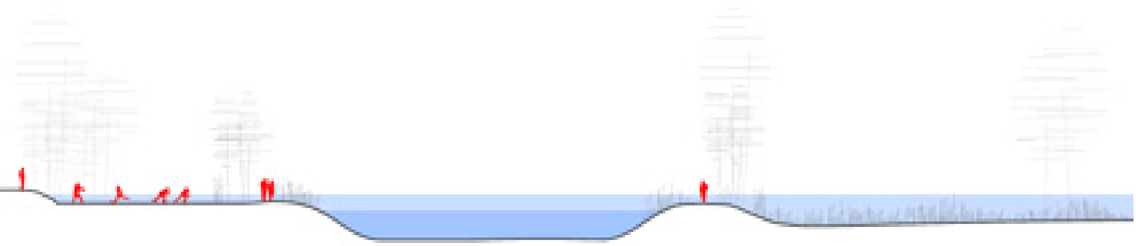


Controlled flood

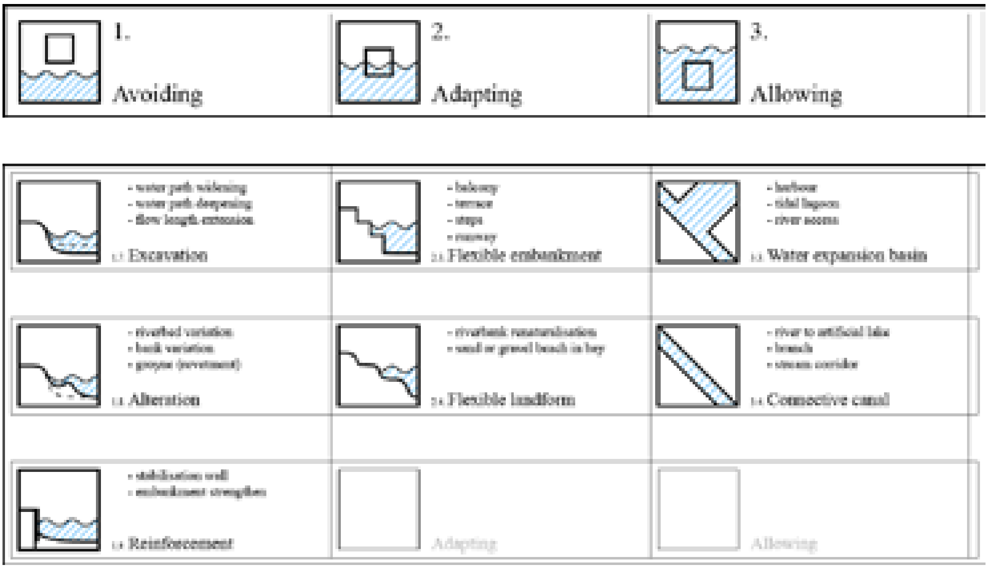
Parks, beaches, playgrounds and lagoons shall be able to cope with floods and tolerate temporary submersion. In case of high water these places ar no longer accessible—or partialy accessible, depending on ground height. Temporary and seasonal facilities, and structures on piles are often installed within these areas. Costly and high-mantainance areas shall be planned on those levels reached by water in extremely unlikely events. Laying and suspended pathways are crucial for floodable areas, since connections allow for the liveability of these spaces even with adverse weather conditions.

Spatial quality
Controlled flood areas perform from flood risk level R1 to R5.
They work ideally in collaboration with flood-adaptive structures, water expansion basin, connective canal, and pileworks. Other associated operations can be mound, suspended pathway, flood-tolerant structures, natural embankment, landform variation, alteration, reinforcement, and flexible landform and embankment. Controlled flood areas can be totally or partially submerged, depending on geo-morphological features.





A. Mill Creek Canyon Earthworks Park - Kent (USA), 1982
B. Conveyance Swale - Dundee (UK)
C. Fields in the Overdiepse polder - Brabant (NL)


1.
Avoiding
2.
Adapting
3.
Allowing
Excavation
Flexible embankment
Water expansion basin
Alteration
Flexible landform
Connective canal
Reinforcement
Adapting
Allowing

Water paths

Avoiding:

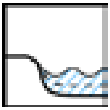
Excavation
Alteration
Reinforcement

Adapting:

Flexible embankment
Flexible landform

Allowing:

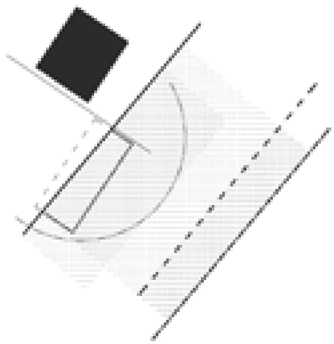
Water expansion basin
Connective canal

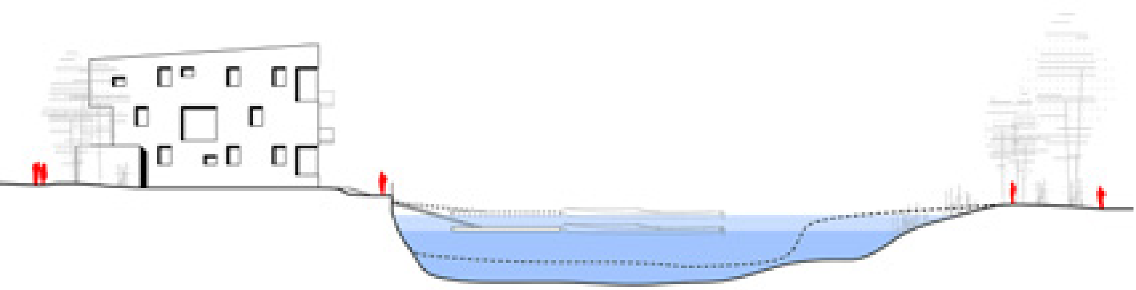


Excavation

Riverbanks' revetment, weirs, and bed's discontinuities can be removed and restored to former river conditions and natural fluvial dynamics. Moreover excavation can bring great benefits in controlling river flow. When a river re-gains its equilibrium in terms of water dynamics and ecosystem, the effects are expanded to the surrounding too. Excavating floodplains, and flattening out the banks provide better control of flows, designing morphodynamic processes.

Spatial quality
Excavation performs properly from flood risk level R1 to R2.
They work ideally in collaboration with reinforce, landform variation, and flexible landform. Other associated operations can be alteration, reinforcement, water expansion basin, connective canal, pilework, mound, and flood-adaptive structures.
Innovation specifically concerns the preservation of balanced ecosystem, and the creation of water dynamics equilibrium.





A. River Havel's riverbed excavation - Potsdam (DE), 2013-2015

B. River Kinnickinnic reconstruction - Milwaukee (USA), 2011

C. River Acushnet's riverbed excavations - New Bedford (USA), 2003

Alteration

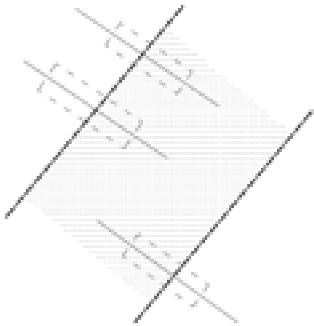
The aim of riverbed alteration is to diversify currents and generally to divert fastest flow from the riverbanks into the centre. To push currents away from banks means the need of lighter interventions on embankments. There are many typologies of current-deflecting elements, such as large single rocks and dead wood (tree trunks), laid and piled stone groynes (rock structures perpendicular to the coast), submerged groynes, bioengineered groynes (living vegetation, gravel, and stones offering valuable habitat for living organisms), and riverbed sills (cross-cutting stone structures).

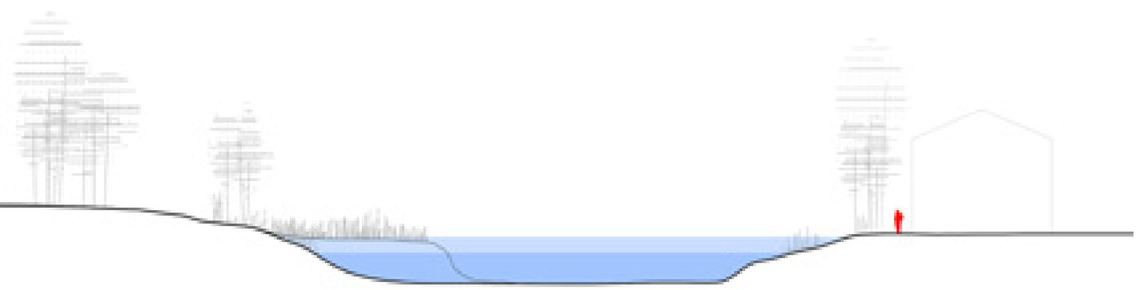
Spatial quality

Alteration performs properly at the flood risk level R1.

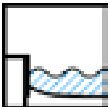
It works ideally in collaboration with flexible landform and connective canal. Other associated operations can be controlled flood, excavation, and landform variation. Riverbed alterations are in total contact with water, and sometimes complitely submerged.

Innovation specifically concerns the preservation of balanced ecosystem, and the creation of water dynamics equilibrium.





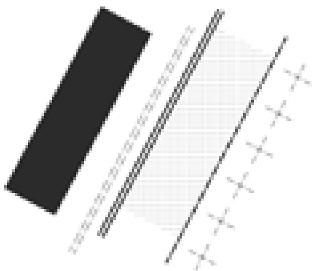
A. Birsvital - Basle (CH), 2002-2004
B. Isar-Plan - München (DE), 2000-2013
C. Floodplain over Lower Rhine - Utrecht (NL)

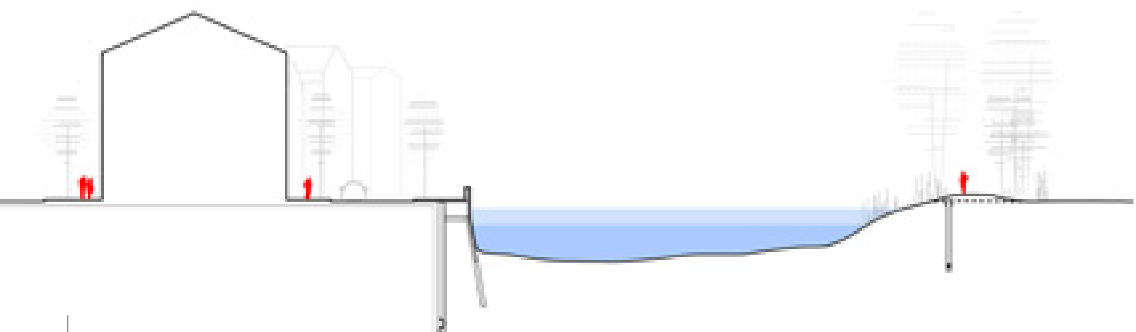


Reinforcement

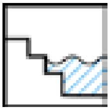
Bank reinforcement limits self-adjusting dynamics of rivers, and are necessary intervention when a floodplain or townscape is not avaible for the watercourse to expand into. Securing process can introduce artificial and near-natural objects and banks to consolidate the embankment. Depending on design strategies, reinforcement works can reduce or highlight flows. Stone revetment represent an artificial way to connect watercourses to the built environment, enhancing the riverbank ecology. Masonry riverbank revetment create vertical walls that can leave space for promenades.

Spatial quality
Reinforcement performs from flood risk level R1 to R5.
It is associated to interventions such as water expansion basin, connective canal, pilework, mound, flood-adaptive structures, reinforce, and landform variation. Reinforcement structures are always in contact with water on one side.
Innovation in technology mainly regards the way these stuctures are integrated in city centres and the landscape.





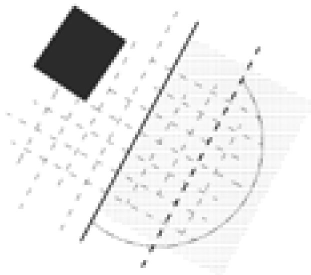
A. Thames embankments' reinforcement during the 1928 flood - London (UK)
B. Hilton's Wharf stability work, eng. Jacobs / Volker Stevin - London (UK)
C. Quai des Gondoles - Choisy-le-Roi (FR), 2009

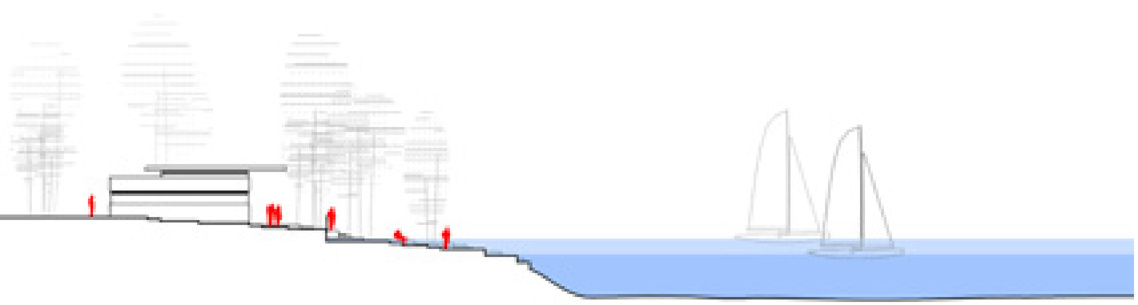


Flexible embankment

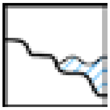
Recreational spaces by waterside can allow for direct access to waterpaths, and be exposed to flooding. Different levels of promenades create intimate places even within city centres, beside guaranteeing the liveability of the area for many divverent levels of high water—to terrace back the bank helps water to spread sideways within its course. The height of terraces determines the level with which they are submerged. Footpaths and cycleways can also be integrated in this riverbank. Linear spatial expansion can be characterised by intermediate levels, terraces, ramps, steps, and stepping stones.

Spatial quality
Flexible embankment performs from flood risk level R1 to R5.
It works ideally in collaboration with flood-tolerant structures, water basin, and connective canals. Other associated operations can be pilework, mound, suspended pathway, flood-adaptive structures, reinforce, landform variation, and controlled flood. Flexible embankment can be partially or totally submerged depending on water level, and the height of each terrace that forms the linear system of the embankment.





A. HafenCity Public Space, EMBT - Hamburg (DE), 2002- 2015
B. Wipkinger Park - Zürich (CH), 2003-2004
C. HafenCity Public Space, EMBT - Hamburg (DE), 2002- 2015



Flexible landform

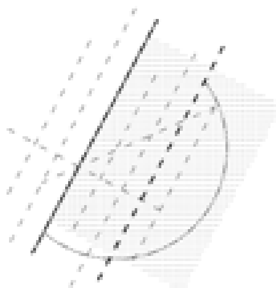
Being part of recreational furnished promenade or standing as part of the lanscape, flexible landform is being flooded in case of high water. Vegetated shores at the edge of watercourses are made of depositing soil material that gets planted, forming green corridors or spot areas along watercourses. These zones offer great help for water-related ecosystems, such as migratory fishes and amphibians. Flexible landform is very tailoed for inner city spaces characterised by concreted, uniform embankments. Planted zones also reduce the danger of falling into water from a promenade.

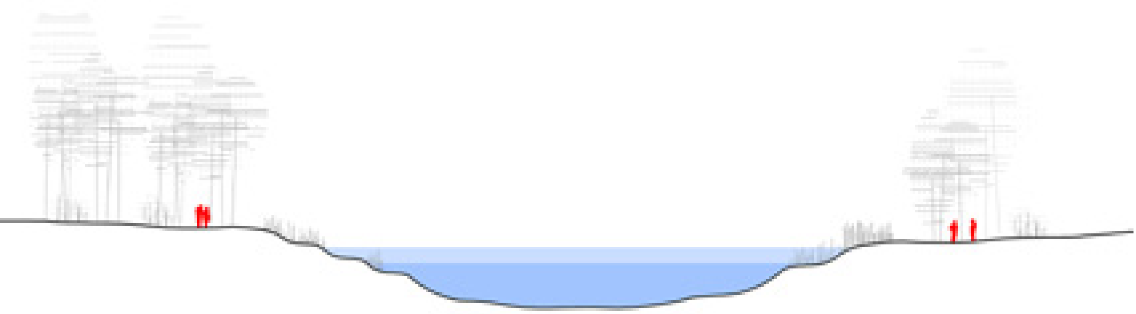
Spatial quality

Flexible landform performs from flood risk level R1 to R5.

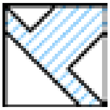
It works ideally in collaboration with pilework, landform variation, excavation, and alteration. Other associated operations can be mound, natural embankment, and controlled flood. Flexible landform can be partially or totally submerged depending on water level, and the height of each green terrace that forms the linear system.

Innovation specifically concerns the preservation of balanced ecosystem, and the creation of water dynamics equilibrium.





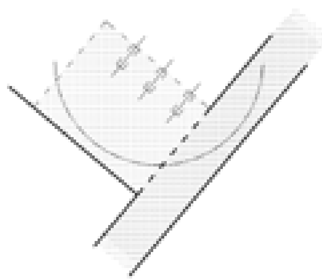
A. Werse's near-natural development - Beckum (DE), since 2001
B. Isar-Plan - München (DE), since 2000
C. Wahlebach's near-natural development - Kassel (DE), 2005

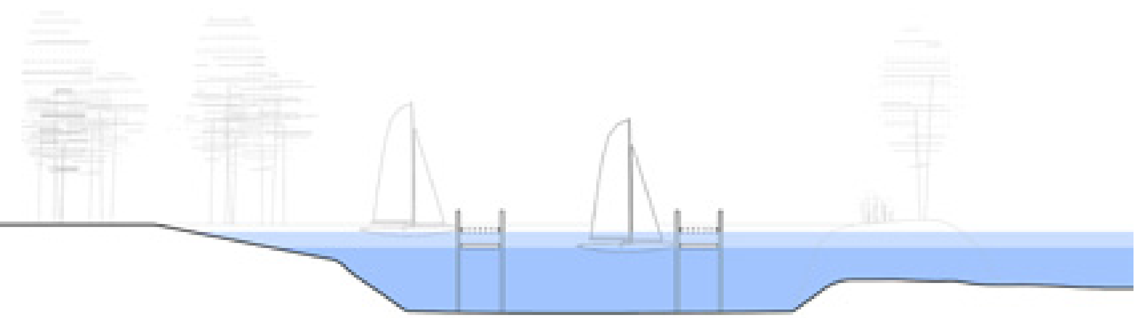


Water expansion basin

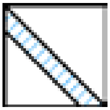
The continuous vertical boundary represented by embankments is broken in some selected locations to access water via ramps, terraces, or floating jetties. The flood limit is pushed back toward the built or natural environment, and it is subjected to the same variations in water level of the watercourse, if not locked. In any case, currents are much weaker, and sediments are concentrated on the side where water flows to. Water expansion basins can be used as bathing beach, waterside playground, boat landing place, or be proper bays where to berth ships, boats, canoe, and so forth.

Spatial quality
Water expansion basin performs from flood risk level R1 to R5.
It works ideally in collaboration with controlled flood and flood-adaptive structures. Other associated operations can be pilework, suspended pathway, reinforce, temporary resistance, landform variation, excavation, reinforcement, and flexible embankment.
Technological innovation specifically concerns the creation of water dynamics equilibrium, and the way these stuctures are integrated in city centres and the landscape.





A. HafenCity - Hamburg (DE), since 2000
B. St. Katherine’s Docks - London (UK)
C. Wallabout Bay and East River - New York City (USA), 1981



Connective canal

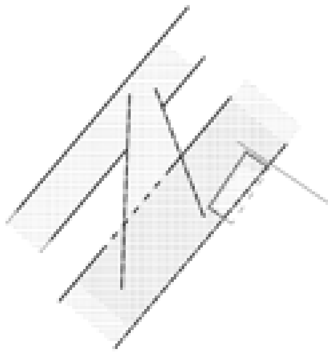
Artificial re-shaping, multiplication, and creation of watercourses are aimed to re-instate natural morphodynamics of rivers, connect rivers to basins or other canals, create new shipping routes, and new branches. Whether within cities or in natural environments, artificial connective canals creates more space for water to flow, decreasing the strenght of water. Natural subsequent development and alterations can only be possible for those watercourses where embankments are not man-made. To have benefits, canals' design process is recommanded to work on a large-scale development of urban- and rural-scapes.

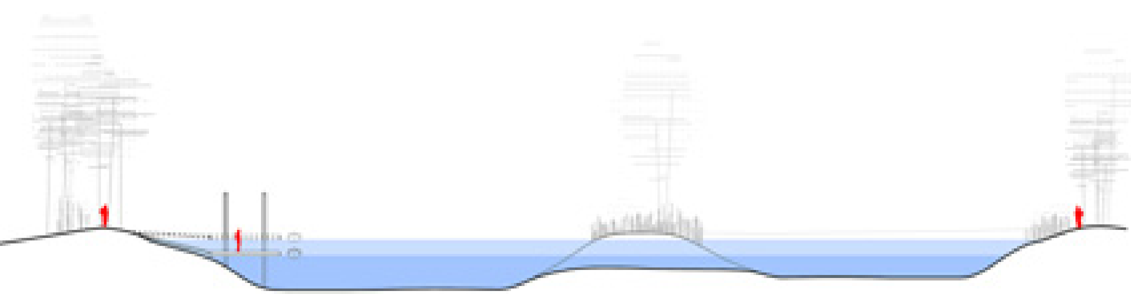
Spatial quality

Connective canal performs from flood risk level R1 to R5.

It works ideally in collaboration with controlled flood and excavation. Other associated operations can be mound, suspended pathway, flood-adaptive structures, landform variation, reinforcement, and flexible embankment and landform.

Technological innovation mainly concerns the preservation of balanced ecosystem, the creation of water dynamics equilibrium, and the way these stuctures are integrated in city centres and the landscape.





A. Byelomorsko–Baltiyskiy Kanal, RU, 1931-1933
B. HafenCity - Hamburg (DE)
C. Restoration of Untere Havel- Havelberg (DE)

Prevention and action

The use of the *Telematic Map of Risk* 3.3.1

On a large scale, proposals for sustainable developments have three preeminent goals to achieve. Firstly, hydraulic engineering works such as dikes and barriers control incoming flows and dissipate tidal energy. Second, upper catchments for fluvial tide, and lower catchments for tidal floods have to be implemented through the creation of expansion areas, establishing new floodplains and building canals and basins. Then, garbage, sewage, sediments have to be managed, in order to preserve the riverbed capacity, and the banks' efficiency. New developments need to take advantage of the combination of political, environmental and economic scenarios, to design a global flood management strategy. Cities must be defended, but at the same time they have to enable trade, working activities, and recreational facilities. On this basis, comprehensive strategies are aimed to set up environmental policies indicating sustainable operative actions, digital and urban infrastructures, and local widespread interventions on the built environment, brownfield areas, and the natural environment.

Working by design, all the principles and strategies we have been evaluating so far provide us with the opportunity to connect policies and guidelines to the real world. As development strategies and factors were identified in previous chapters, we are now going to study the pilot case from a dynamic point of view.

Complex societies, formed by political-economic, social, and environmental systems, act within a wider complex system, represented by the climate, immigration, communication technologies, and so forth. These entities 'do obey nonlinear laws of self-organization' (K.Mainzer, 2007). They all are dynamic elements influencing one another, and the dominance of one of these on the others causes upheavals and disconcert on its complementary systems. It is possible though to simulate and manipulate their interactions, investigating complex patterns and behaviours. Self-organising change challenge architectural technology, allowing for continuous feedback from the physical world, and providing precise models and predictions. Technologically grounded optimisations of models (A.Gleiniger, 2008) based on real phenomena are always part of a socio-political and design strategic vision. In this perspective, the main interest is based on the idea of societal self-organisation. The creation on socio-environmental flexible models allows for actions to put into practice on the territory. Complexity, albeit fascinating as an artistic-aesthetic category, has its structure founded on technical-constructive manifestation.

To transfer these principles to architecture, we must be aware that non-linear dynamics cannot be represented, analysed, and planned through traditional planning methodologies. In fact, as temporal coordinates enter planning process, standard maps are definitely out to date. In the light of this, computational design opened up new possibilities in displaying acute sensitivity about interdependent dynamics. Self-organising systems, based on self-organised behaviours, are moulded by the many interacting entities forming a decentralised system. One of the constitutive bases of Modernity is the notion of 'complexity' (C.Bellut, 2008), which is determining socio-political policies contextually with the power of technological progress and economic critique. Despite all the domains involved, complex systems follow mathematical laws that can be studied and represented through diagrams. Moreover, since complexity is analysed mathematically, it can also be modelled according to these laws. Complex systems can thus be anticipated through mathematic relationships between spatial entities. The forward-looking planning process shall be explained below in this chapter, but firstly we need to complete the discussion of Chapter 3.1.2 regarding 3D flood risk analysis (Fig. 3.12). Now the analysis will be conducted on the pilot case, the site between the boroughs of Newham and Tower Hamlets.

Architects often consider their development site as *carte blanche* where to freely design their aspirations, rather than the opportunity to meet current social issues and future needs. In the reality, there are always some aspects to unveil. Digital devices can project these invisible realms that necessitate to be considered.

Once all the useful data from the *Digimap Ordnance Survey* dataset

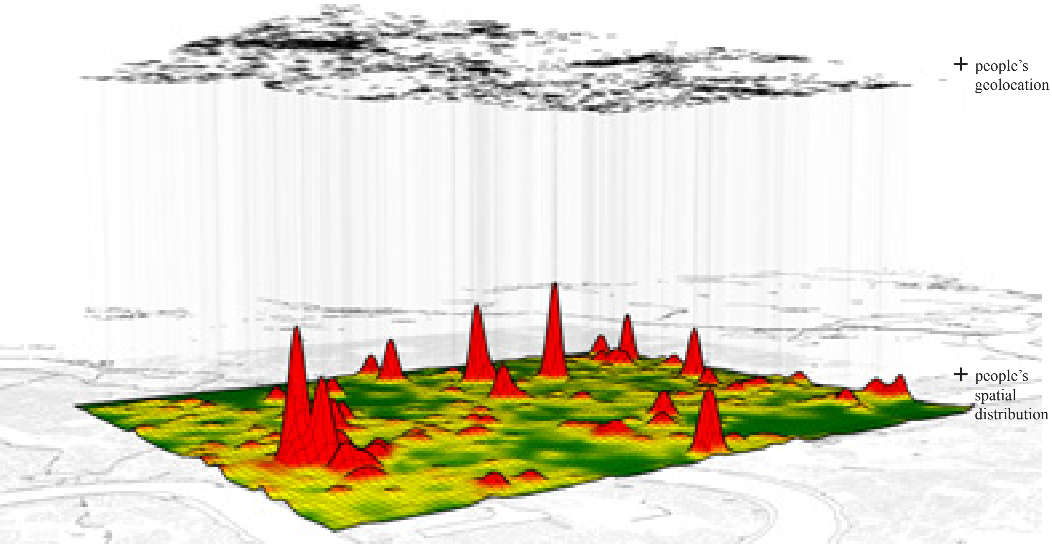


Fig. 3.8
Spatial correlation between Twitter data, and the natural and built environment.

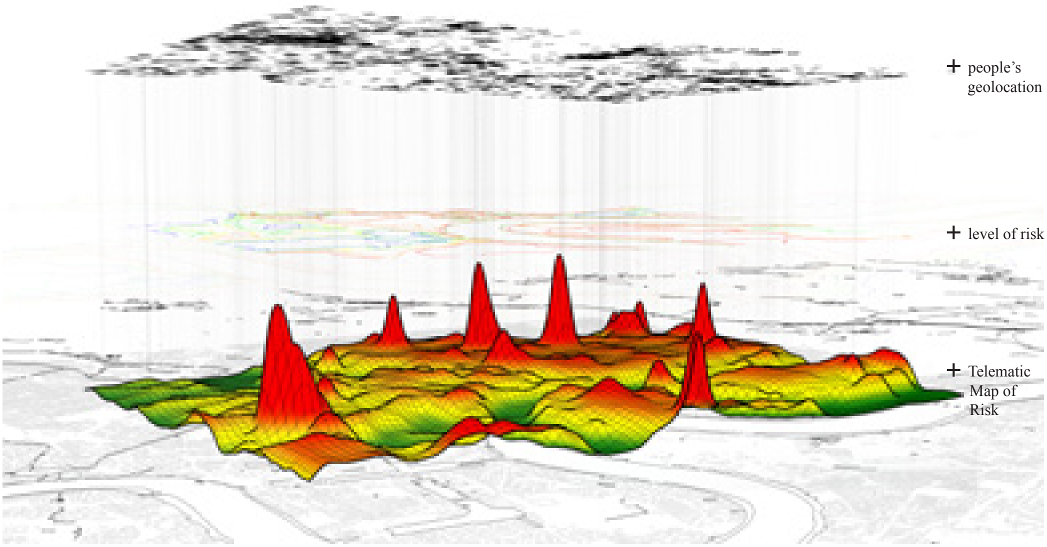


Fig. 3.9
Spatial correlation between Twitter data, the natural and built environment, and the level of flood risk.

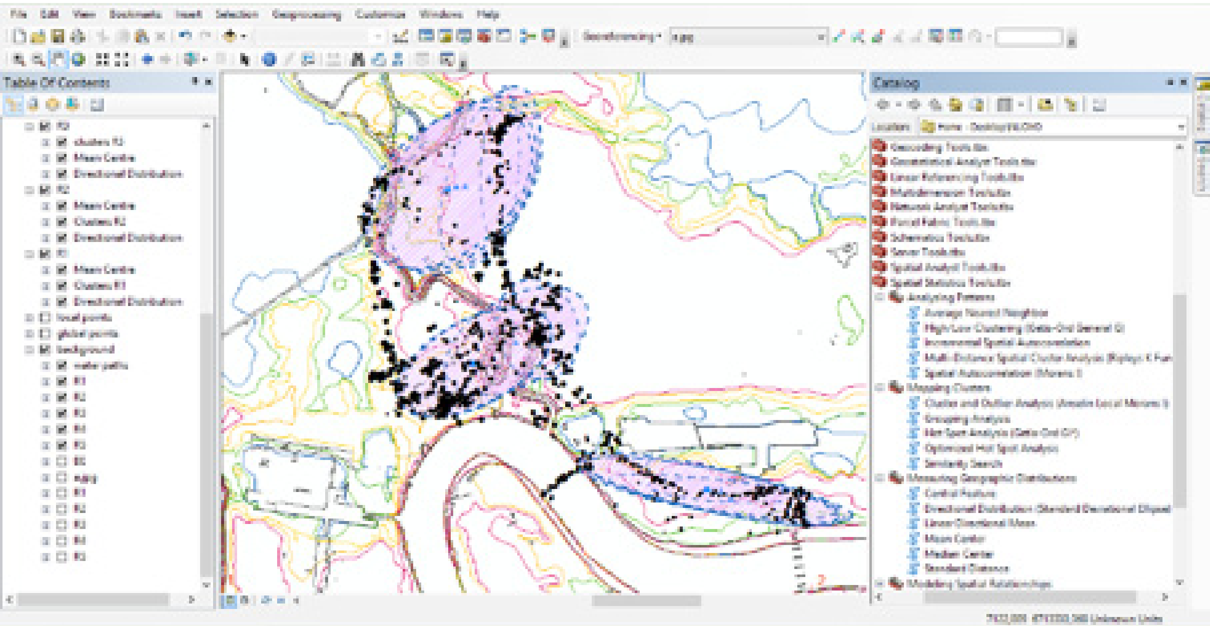


Fig. 3.10
The *Telematic Map of Risk on* ArcMap. ‘People’s location’ and ‘levels of risk’ layers on.

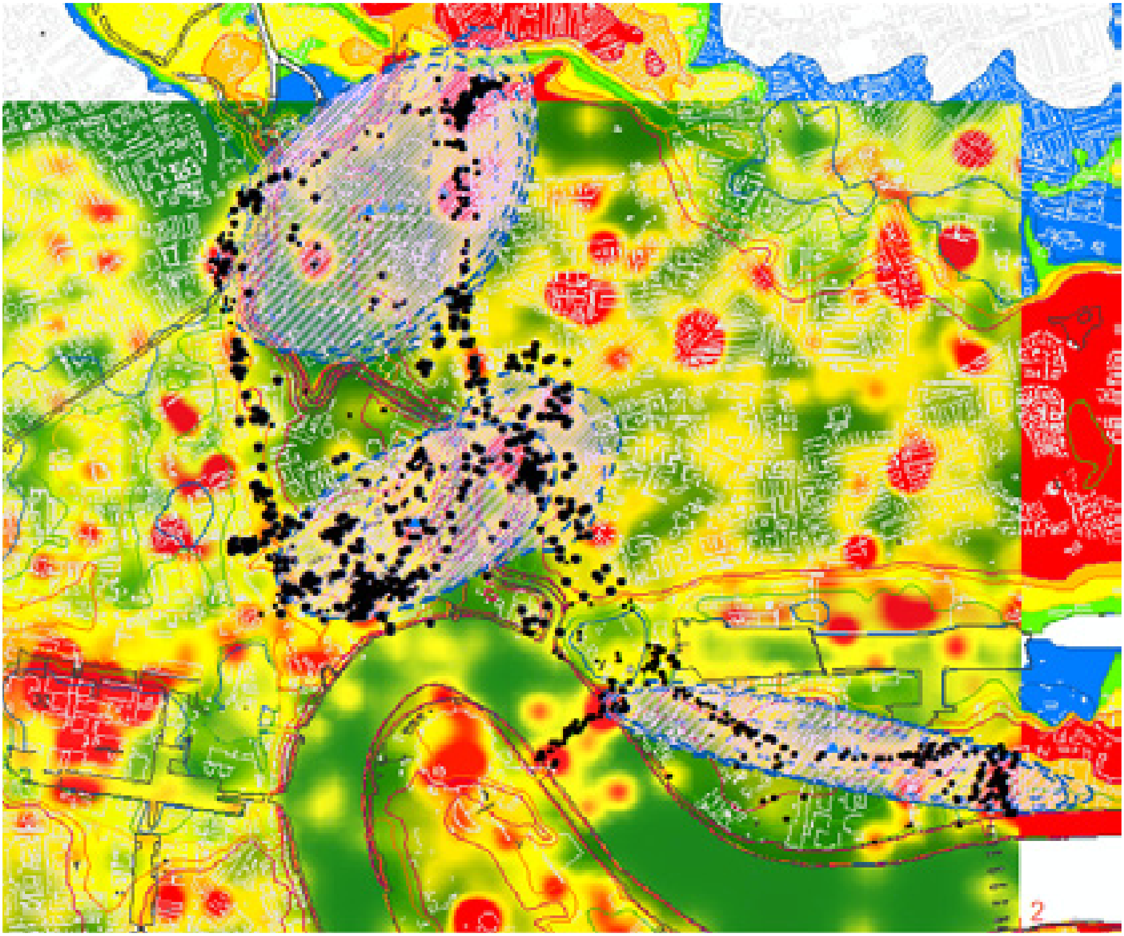


Fig. 3.11
The *Telematic Map of Risk*, with full layers.

is gathered, its layers shall be transferred onto the GIS software *ArcMap* (the geographic information system for overlaying maps previously described.) People's location is assessed through *Mosquito*, a plugin suite developed for Rhino and Grasshopper by Studio Smuts.[1] The plugin allows us to draw benefits from exact location, date, and contents of posts from social networks such as Facebook, Twitter, Topsy, etc. The consideration of public realms, which is one of the main aspects of architects' responsibility, drives us to merge the digital and the physical domains. This is possible considering mobile and computer technologies i.e, the exchange of data, as part of the design process. Of course, as this data are complex and impure, data analysts must select the right questions for the electronic devices, in order to obtain focused information.

Along the same lines as the he celebre traffic studies by Louis Kahn, showing the existing traffic movement in Philadelphia, Figure 3.8 shows how people are distributed on the pilot case area. (To clarify the method once again, the surface obtained does not represent each single person's location, but the average distribution of people, based on the geolocated tweets they post.) The study reveals the highest concentration of people, corresponding to the red peaks, for instance at Canary Wharf and the Greenwich Peninsula, and the lowest one, see the green path of the River Thames and the upper part of the study site. Then, we need to correlate this information to the local level of risk, following the same criteria adopted for the wide study on London (see Plate 3.12). The surface of Figure 3.9 is the outcome of this relation, and it is clear how sensitive the improvement of the quality of information is. The territorial features along the river almost coincide with the physical characteristics of the landform, proofing that the gap between digital and physical realms is smaller than what anybody could predict. Moreover, the case study area and the site next to the Greenwich Peninsula, which were quite flat in the first surface, are now characterised by a more vary one, which corresponds to an important level of risk. The methodology for the creation of these studies, on *Rhino Grasshopper,* is detailed in Appendix B, Section A3.

As well as the *Telematic Map of Risk* over the London's *FWAA*, the spatial correlations between Twitter data and the five levels of flood risk on the pilot case indicates the areas of higher priority of action. 'The resilient city implies finality' (L.J.Vale, T.J.Campanella, 2005) to regulate or conform on-going projects, and foster future developments. Yet, it is usually seen as a 'closure' process, rather than a highly productive openness to

[1] http://www.studionu.net/ceed3/mosquito/

future environmental conditions.

These information can also be analysed on *ArcMap* (Figures 3.10, 3.11), in order to mathematically process the data gathered. Each geo-processing tool on *ArcMap* (right-hand side of Fig. 3.10) achieves an operation on geographic data that produce a new dataset as result. Then, the outcoming data can be processed again by other tools. Using spatial analysis it is possible to combine data from many sources, in order to produce more complete and sophisticated set of information. Geospatial analysis can be conducted utilising the unveiled correlations. Discrimination criteria to select the useful information are based on four parameters aimed to consolidate disconnected territory, i.e. water dynamics, public spaces' features, the local level of risk, and the building state. After having determined spatial areas of influence—those parts of the territory divided by main infrastructures—it is possible to measure people's geographic distribution (mean centre[2], directional distribution[3]), and mapping clusters (Moran's I[4]) within each area of risk.

A. *The mean centre*
B. *The Directional Distribution*
C. *Clusters*

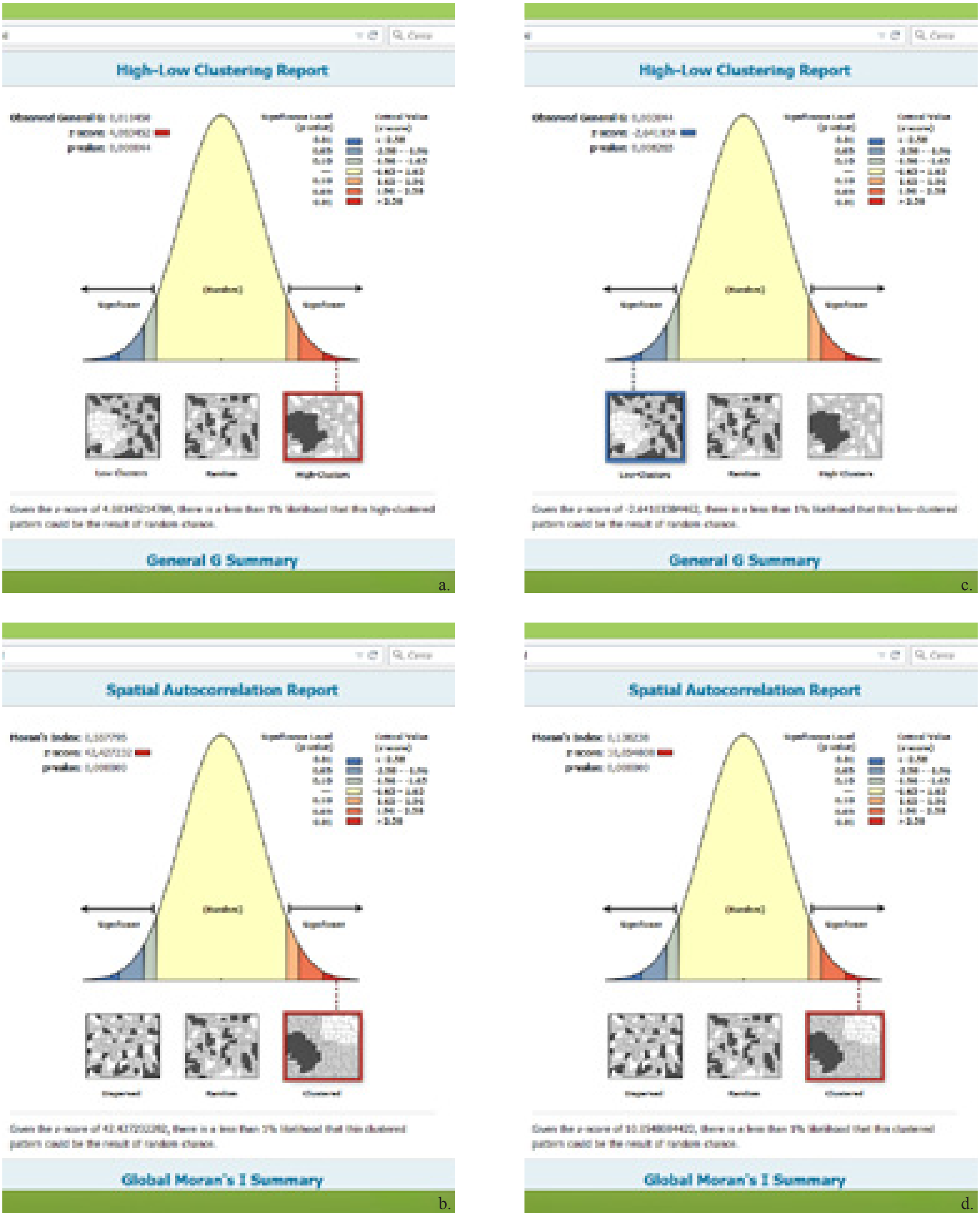
A. *The mean centre.* This tool identifies the geographic centre, a point constructed from the average x and y values of all points. (Z values are automatically predetermined by the local level of risk itself.) This tool is highly useful for regulating where to place a safe location in case a catastrophic event occurs (see Ch. 4.1). As the mean centre is mathematically identified, the most suitable building/site can be equipped in order to guarantee the highest standard of safety for one or more phenomena, and one or more levels of risk (depending on the mean centre of each).

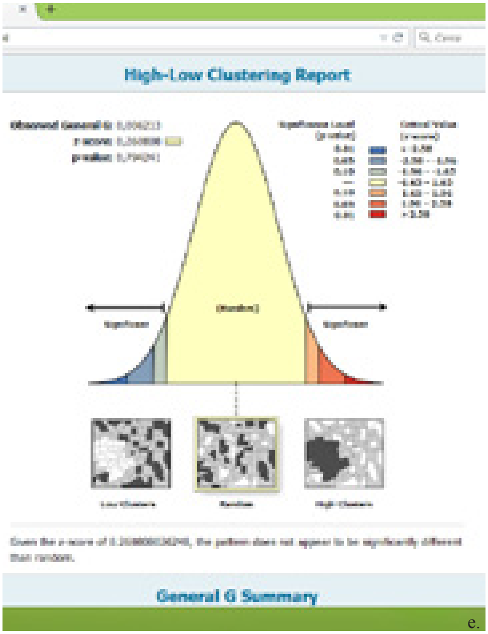
B. *The Directional Distribution.* The clusters' map tool recognises statistically significant hot spots, and spatial outliers, using the *Anselin Local Moran's I* statistic, while the directional distribution tool creates deviational ellipses to outline points' geographic features: central tendency, dispersion, and directional trends. A deviational ellipse for each level of risk

2 http://resources.esri.com/help/9.3/arcgisdesktop/com/gp_toolref/spatial_statistics_tools/mean_center_spatial_statistics_.htm

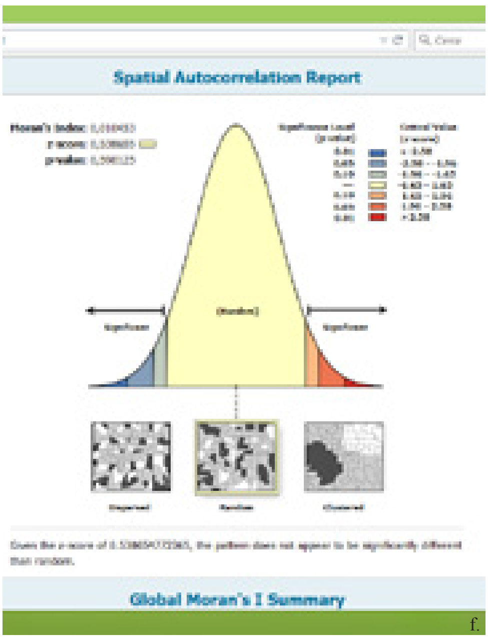
3 http://resources.esri.com/help/9.3/arcgisengine/java/gp_toolref/spatial_statistics_tools/directional_distribution_standard_deviational_ellipse_spatial_statistics_.htm

4 http://resources.esri.com/help/9.3/arcgisengine/java/gp_toolref/spatial_statistics_tools/cluster_and_outlier_analysis_colon_anselin_local_moran_s_i_spatial_statistics_.htm


High-Low Clustering Report
General G Summary
a.
High-Low Clustering Report
General G Summary
c.
Spatial Autocorrelation Report
Global Moran's I Summary
b.
Spatial Autocorrelation Report
Global Moran's I Summary
d.



e.



f.

Plate 3.17
Geospatial analysis. Spatial autocorrelation andHigh-Low Clustering reports for R1, on the pilot case. By the Author.

in three different areas of the pilot case is calculated. These three sectors were previously identified considering the map of clusters, and the disconnections caused by infrastructures such as the River Lee, the railway, the DLR (the Docklands Light Railway), and highways. The aim of the five directional ellipses (Figures 3.10, 3.11), from R1 to R5, is to understand people's concentration for each one of the levels of risk. These provide information about the seriousness of the risk, looking at the dimension of the ellipses, the shift of the mean centre, and the direction of the axes. In doing so, one can evaluate what the shift of large massing from a specific area to another one is, and trace new directions for future developments.

C. *Clusters.* The typology of clusters for the three sectors, highlighted by the concentration and dimension of points in Figures 3.10 and 3.11, is analysed in the diagrams of Plate 3.17, following the principles of Geospatial Analysis introduced in Chapter 2.3.2. In fact, the Spatial Autocorrelation Report,[5] carried out as sample for R1, indicates whether the points—i.e., the concentration of people—are grouped as clusters (b, d), dispersed, or randomly gathered (f) all along one area. Then, the analysis proceeds with the evaluation of the clusterisation intensity, through the High-Low Clustering Report[6]. In the specific cases of R1, the first sector (the top one) is characterised by a high-clustered series of points (a), while the second sector (the central one) has a low-clustered distribution (c). The third area, classified as a 'random distribution' in the Spatial Autocorrelation Report, is assessed as 'random' in the High-Low Clustering Report too.

'Directional distribution' and 'clusters' map' are helpful to detect the areas where people are passing through the most, and the main direction of masses. Through these tools, new boroughs were identified on a large scale in Chapter 3.1.2. On a smaller scale their importance is much more related to dynamic processes. Plate 3.18 (a) reports R1 and R5 ellipses and the direction of their main axes, and connect these to the distribution of points and their main clusters. At this stage, the active role of the architect is crucial. Indeed, now s/he begin a logic process toward the definition of a series of relationships between the natural and the built environment, and human behaviours. In terms of large interventions, the role of the architect is not about the conception and construction of the form[7] but, understanding the environment, to try to establish his/her tasks within the relentless progress.

5 http://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/spatial-autocorrelation.htm

6 https://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/high-low-clustering.htm

7 Ratti C., Claudel M., 2015, *Open Source Architecture*, Thames and Hudson Ltd, New York.

The sequences of the *Cluster Plan* (Plate 3.16, 3.17) are diagrams aimed to connect procedures coming from Information Technology, such as the ones described so far, to architectural models and environmental features. Anticipatory models meet thus the real on-going world. Through diagrams, architects have to work on this dichotomous system. In fact,

> "[...] the diagram becomes a condensation of architectural ideas and a metaphor or expression of the biological quality of the complexity of life as such."[8]

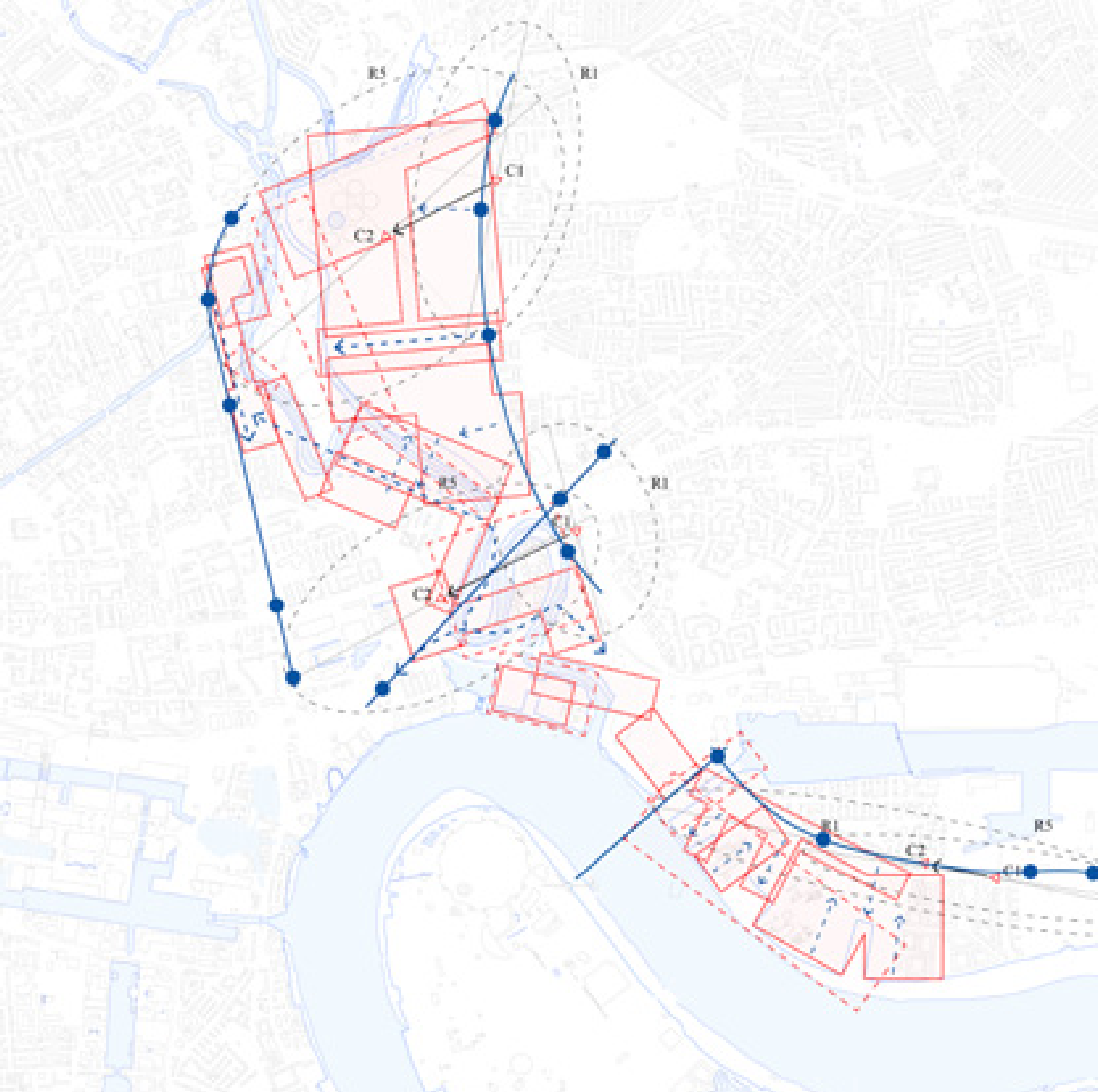
Being flexible by nature, it can record evolutionary processes, and provide impulses for new developments at the same time. Any cluster represented in diagrams does not have its own structure and neither a steady hierarchy, because of the temporary condition of phenomena that a dynamic process presupposes. The use of diagrams by architects hence means to achieve the highest level of democracy, as data comes from geophysical and mathematical models. Points and lines imply meanings and processes that only the architect can develop, aimed for the creation of environmental scenarios. Dynamic messages passing through the space need both computers to be fully understood, and humans to convert those messages into something humane. 'What passes may be a message but static prevents it from being heard, and sometimes, from being sent.' (M.Serres, 1996) All the studies of this research show invisible and indeterminate realities allowing for a denser way to conceptualise the city to come. The diagrams on Plates 3.18 and 3.19 show in two dimensions a four-dimensional domain.

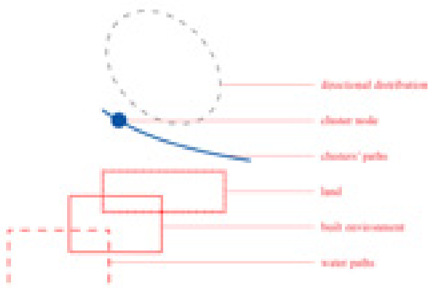
Points and lines, representing people's concentrations, create a certain tension with the landscape and the built environment. This is so, both in terms of shapes, and in terms of intensity of spatial entities. These relations suggest, because of their very nature, precise operations on the territory. Naturally, they are not univocal actions, neither considering infrastructural operations nor in terms of structural interventions on the natural and built environment. In fact, architects give their readings of models, being aware of the direction and consistency of future phenomena.

The first step is to identify sectors of interventions, in connection to the outcomes of the previous analyses (Plate 3.18 b, 3.19 a), and depending on the category already grouped as 'built environment', 'land', and 'water paths'. Each one of these shall determine the priority of action of cluster

[8] Keller S., 2007, "Systems Aesthetics, or how Cambridge Solved Architecture". In Anstey T., et al. (eds), *Architecture and Authorship*, Routledge, London.

Plate 3.18 (a, b)
Cluster plan.


R5
R1
C1
C2
R5
R1
C1
C2
R1
R5
C2
C1



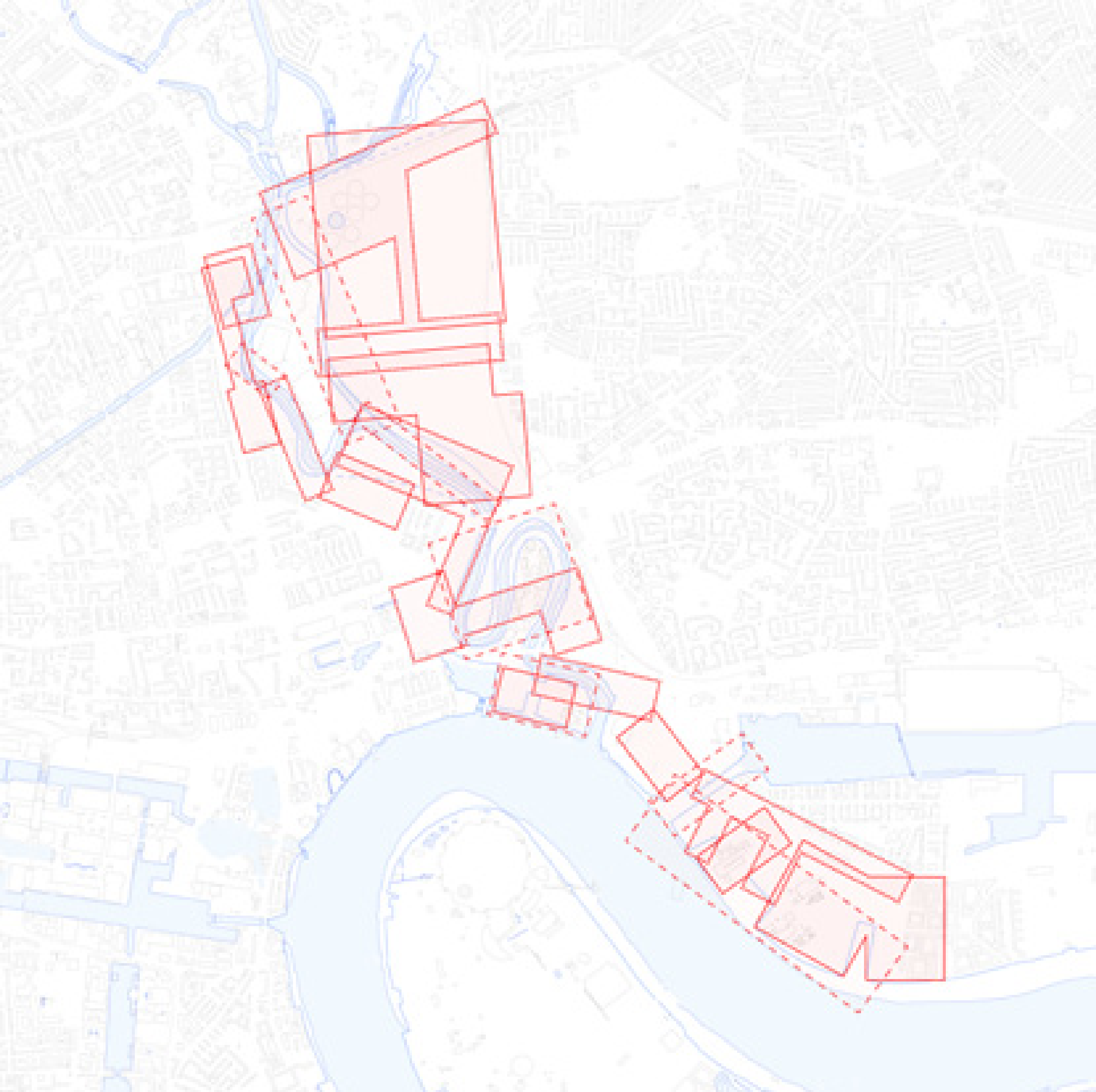
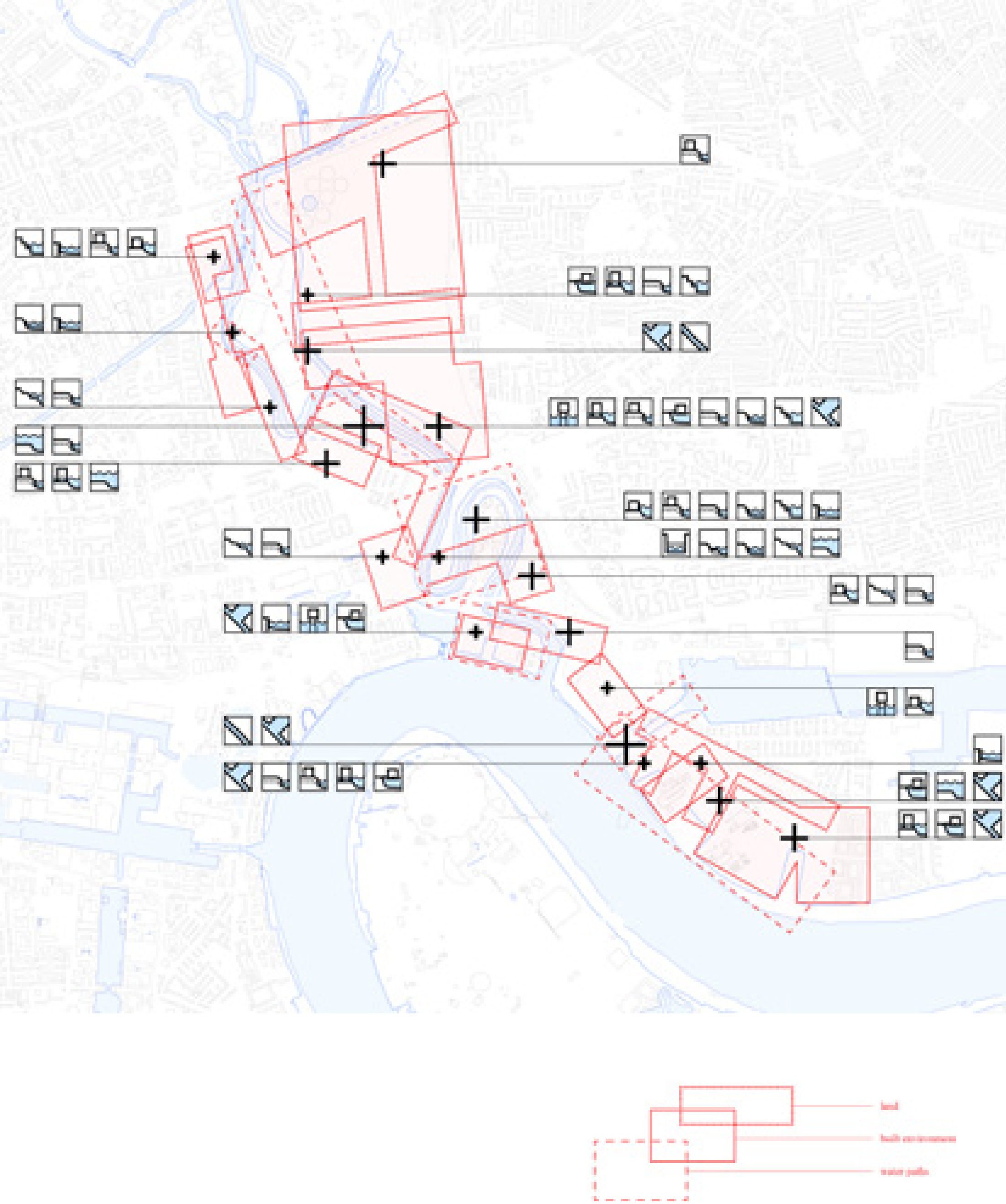
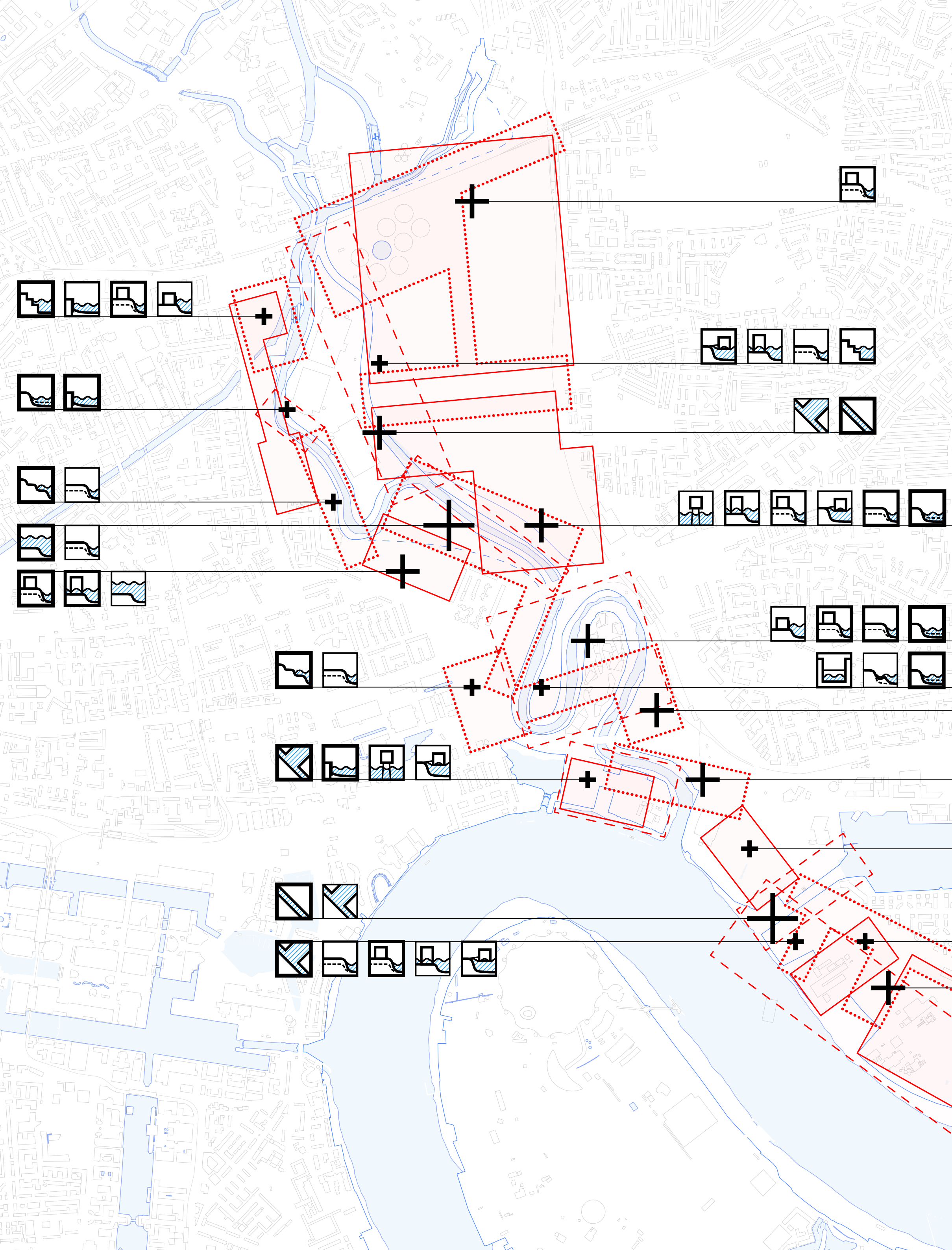
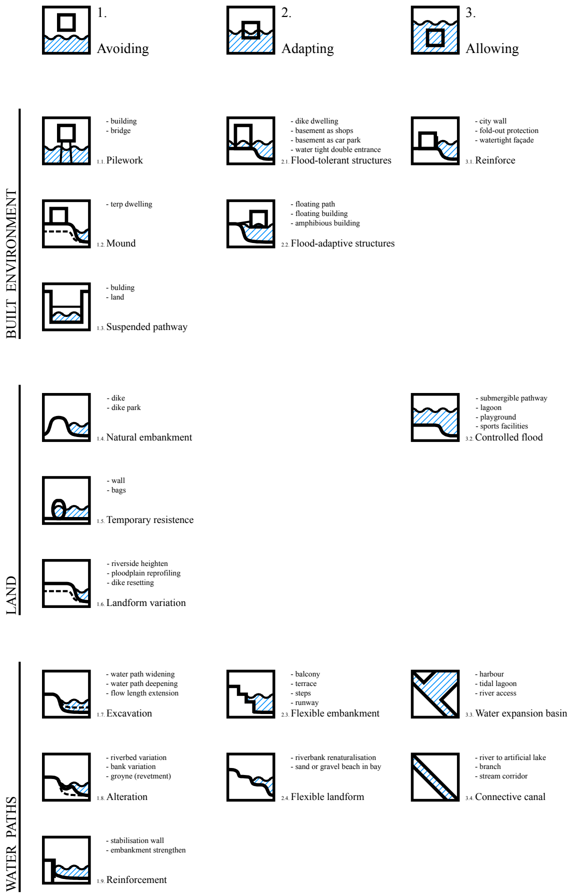


Plate 3.19 (a, b)
Cluster plan areas and possible actions.







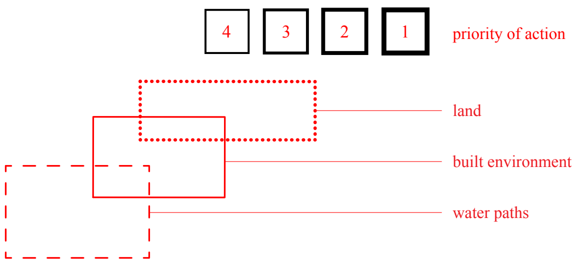


Plate 3.20
Cluster plan outputs.

plan outputs. These sectors are interconnected, so that planners can make working together the actions of *avoiding* built and environmental entities to be involved in water dynamics, creating *adaptive* systems, and *allowing* water to take possession of the territory (see Ch. 3.2.2). The criteria for creating correlations between sectors are based both on current land uses and on future developments, with a view to the dynamism of transformation processes.

In second instance, the possible actions on each sector are evaluated. These are chosen from the guidelines, depending on the sector and the relative category (built environment, land, and water paths). Of course, when sectors are overlapped, the priorities of actions belong to more than one category. It is important to stress that the guidelines (see Plate 3.15) are a flexible scheme that necessitates to be integrated or changed over time, with new strategies, proposals, and technological solutions. It is not a steady, definitive approach to water dynamics. So, the task of the architect is now to indicate the most reasonable solutions according to the relational diagram of Figure 3.5 (Ch. 3.2.2). This methodology allows for the definition of a flexible infrastructure—that is the adoption of the same criteria of the guidelines—capable to guarantee the highest flexibility of individual interventions all along the entire territory. Thus, architects are free to govern their design principles, 'plugging' their projects into the common strategic plan. In doing so, the scheme becomes an operative, flexible tool to design the variation of sites over time. It is adequate to undergo constant alteration, depending on the needs and changes of the society and the environment i.e., the whole ecosystem.

Infrastructure recognises the importance of uniqueness yet, at the same time, it moulds a complex system of interconnections between these 'islands of use'. Hence, topographic variations create a wide variety of situations (see Ch. 3.2.2) and relations with water, allowing for the formation of networks of activities and social challenges. The structure of circulatory systems is of primary importance in the definition of water boroughs, and to get the land connected to water. New developments are the hubs of the system that shall be established, trying to create a continuity of different infrastructures—digital, water-driven, and land-based. The importance of the infrastructural spine is also highlighted in 'Water Proving Ground' by LTL Architects,[9] one of the architecture firms selected by MoMA for the workshop and exhibition, *Rising Currents* (2010). 'Integrating water as a performative component of the design, the project proposes a vibrant am-

[9] Paul Lewis, Marc Tsurumaki, David J. Lewis. New York. http://ltlarchitects.com

phibious landscape continually activated by rising tides.'[10]

But it is not just regarding circulatory systems that the city is time sensitive. In fact, every anticipatory development projects deals with the uncertainty and indeterminacy of time. For this reason, the next step of the cluster plan is to identify priorities of actions. In Plate 3.20, four levels of priority are connected to the actions allowed in each sector. They depend primarily on their impact in decreasing the level of flood-risk over time. These are divided as follows:

1. *high priority:* main core of the infrastructures
2. *mid-high priority:* main structural interventions
3. *mid-low priority:* secondary infrastructural works
4. *low priority:* secondary structural interventions

The highest priority (1) is given to those actions whose construction is subjected to its connection with existing infrastructures. They are so crucially important because they can join two or more different kinds of infrastructures. Then, main structural interventions (2) follow the infrastructural ones in terms of urgency. They are all those constructions directly connected to the main infrastructures that are not strictly necessary for their interconnections. Mid-low priority (3) regards the infrastructural works that are connected to the main infrastructures through specific hubs and clusters of buildings. Finally, lowest priority (4) is given to those actions that do not need a direct connection with the main infrastructure, but that can be connected to a secondary one, through the interventions of the second and third classes.

The outputs coming from the cluster plan (Plate 3.20) show two different approaches, depending on whether the connection is stronger with residential areas (left-hand side of the plan) or the industrial ones (right-hand side of the plan). This choice implies the use of more land-related infrastructural decisions for the first case, aimed at reconnect the built environment to the River Lee, which is currently cut apart by the highline. For instance, it is planned to design mounds, flood-tolerant structures, flexible landform, and so forth. On the other hand, industrial areas are more subjected to works that intend to revitalise the connection between the built environment and water paths in terms of use of the infrastructures. In fact, these interventions mainly regard reinforcement works, and the creation

[10] http://www.moma.org/explore/inside_out/category/rising-currents
Bergdoll B., 2011, *Rising Currents: Projects for New York's Waterfront*, MoMA Museum of Modern Art, New York.

of new water expansion basins and canals.

All in all, the importance to connect diagrams to integrated typologies of interventions is vital for planning process. Architects are provided new analytical tools by advancements in technology. Indeed, this chapter was aimed to show one of the possible connections between digital realms and the real world. There is no future disconnected to digital technology that could be fully controlled by architects. The demand for highly specialised skills is often a comfortable alibi to keep the *status quo* untouched. Hence, architects build up their critique to current society, wasting their time in talking, instead of designing.

> "[A]n architecture that works exclusively in the semiotic register and defines its role as critique, commentary, or even 'interrogation' (laying bare of the intricacies of architecture's complicity with power and politics) has, in some fundamental way, given up the possibility of ever intervening in that reality."[11] [A building was once] "an opportunity to improve the human condition; [while nowadays it is often conceived as] an opportunity to express the human condition."[12]

By the creation of merely theoretical discourses to justify architectures made out of sign and personal aspirations (or clients' aspirations), architects miss the contact with the reality. Indeed, they have been building pieces of architecture, more or less repulsive, or more or less fashionable, avoiding thinking of the future of the environment and the society. Now the argument is different: it is about the liveability or not of entire cities.

Yet, being not an omniscient entity, the architect needs a team of experts from other sectors. The topic of technological transfer from disciplines related to architectural technology was already introduced in Chapter 2.2.2., in terms of knowledge *per se*. Particularly, it was expound the contribution of digital technology, geospatial analysis, and physiography. Moreover, in the last chapters, it emerged the key role of disciplines such as hydraulic engineering, anthropology, risk management, politics, and economy. The architect only cannot manage the whole strategic design process: s/he needs the help of the following professionals:

[11] Allen S., 1999, *Points+Lines, Diagrams and Projects for the City*, Princeton Architectural Press, New York.

[12] Evans R., 1992, "Bad News". Paper delivered at the conference on *Theory and Practice in the Work of John Hedjuk*, Canadian Centre of Architecture, Montreal.

- *physiographers & geoanalysts:* study relationships between spatial entities, and between the territory and social phenomena; analyse data and produce mathematical models to understand (past to present) and anticipate (present to future) events on a territorial scale. Their role is crucial in connecting data provided by data analysts to territorial entities, on the *Telematic Map of Risk*.
- *data analysts & computer programmers*: the first import and clean data, to acquire information about specific topics, trying and formulate correlations between different datasets; they validate data models with the goal of understanding social phenomena, for decision-making purposes. Their work is in tight synergy with programmers, whose task is to write and improve software, and develop logical structures (algorithms) for solving problems by computer.
- *anthropologists:* study people's behaviour especially in connection with community's threats; they analyse future aftermaths caused by strategic plan decisions. They bridge cluster plan to design process.
- *infrastructural, structural & hydraulic engineers*[13]*:* deal with infrastructural works such as dykes, levees, and barriers, and manage the relation between infrastructures and floodplains; study how to improve watercourses and technological solutions; design structures of the built environment. They work at the master plan during the preliminary design phase mainly regarding infrastructures, and in the detailed design on both infrastructural and architectural domains.
- *risk managers:* identify, assess, and prioritise local and global risk, and secondary hazards that a threat or a planning decision could cause. Their tasks are crucial at the very beginning of any strategic planning, and during the master planning process.
- *economists:* study a society's resources, and assess which laws are economically efficient for future developments; they work with Local Agencies and Trusts, to study the effects of laws, and improve their operative achievements.

Having understood the limits and the role of the individual professionals, the task of the architect is missing. His/her role is not to simply coordinate all the people of the team, and not even to decide at which stage and with what importance during the decisional process they are needed. First of all, the architect identifies strategic goals, through the evaluation

[13] This is the case of flood management. Of course, depending on the hazard, this professional can be switch to seismologist, volcanologist, and so forth.

of strengths, weaknesses, opportunities and threats involved in a project. S/he determines the phases of the process, identifying the key-steps of the design, and evaluating the actors to whom each tasks is given.

To date, architects have confined their profession to binomial relations with digital realms and environmental problems. This dissertation proves how architecture, digital technologies, and environmental issues cannot kept disjointed to design the cities to come. A new generation of architects is needed.

The role of the 'architect 3.0' as playmaker of the team concerns both the design of the methodological process, and the design of operative strategies for territory planning and the built environment. (The number 'three' implies the inseparability of the three components architecture, digital technologies, and environmental issues.) In the context of strategic planning, the *architect 3.0* focuses on clearly defining objectives, leading the team towards societal resilience, and environmental sustainability. S/he takes decisions about the opportunities of development and technologies to adopt, aided by the professionals seen above, and provides the global direction, guiding and defining the overall strategy. Through his/her decisions, it becomes pragmatic design over the entire process. Moreover, from the ideation phase onward, s/he is the executer of innovative ideas and opportunities for the city to come.

Like music conductors, architects are the final responsible of the concertation of all the professional figures coordinated—as proof of the importance of his/her intellectual work. But most importantly this new professional figure knows *what* to do and *how* to operate to turn the immaterial world into a physical dynamic reality. Indeed, the *architect 2.0* goes far beyond the mere theoretical aspects of the design process; s/he is not just the strategic coordinator of actions, but shapes the actions for the city to come. His/her role is to determine the priority of operative strategies aimed to lower the level of risk over the territory mostly subjected to disasters and to future likely catastrophic events.

Shifting the level of risk 3.3.2

The distinction between catastrophe and disaster contains the very meaning of 'resilience', whose main feature is the flexibility of the natural and built environment. Since neither catastrophes nor disasters are static, resilience cannot be a fixed state but, rather, a process. Prevention and

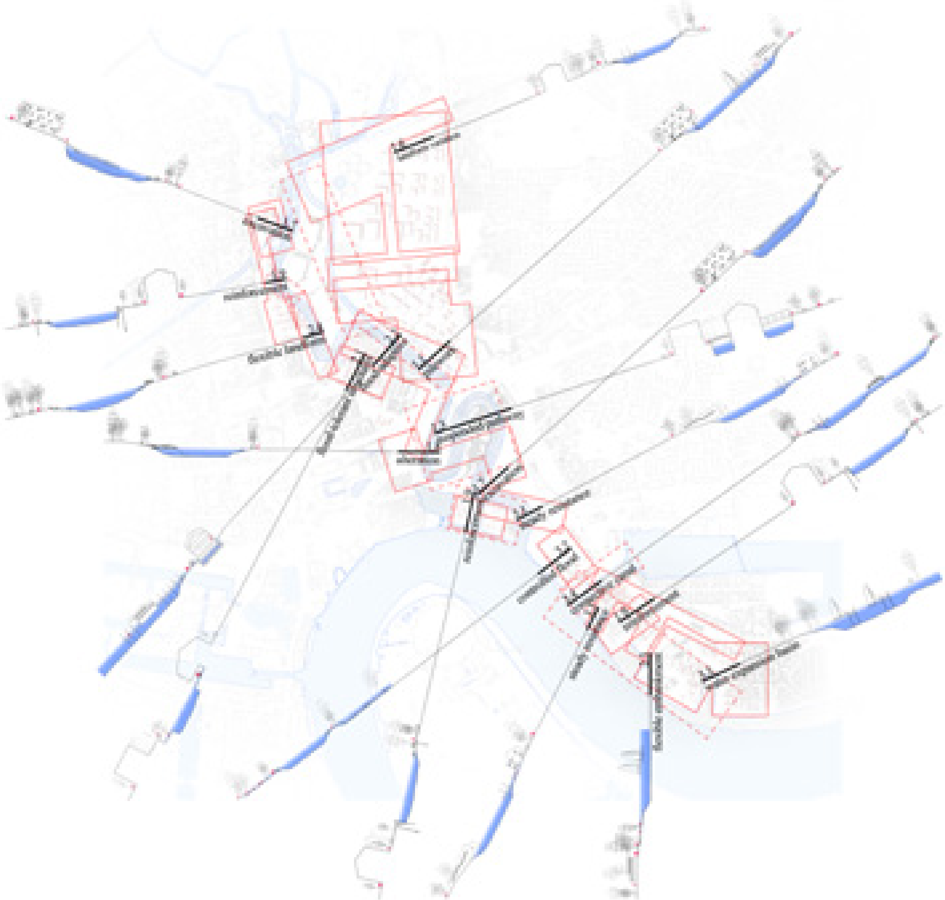


Fig. 3.12
Spatial entities' main actions for.

preparedness are the basis of a disaster-resilient community. The first one regards operative strategies to tackle environmental changes; the second one is about socio-political systems of information of the commonalty. They both are determined by strategic planning, whose process towards a resilient society is built onto three main issues, as follows:

physical: assessment & decision-making process
cultural: spiritual uniqueness
economic: operative tools & job creation

Physical realm concerns both the assessment of global and local level of risk, evaluated through the *Telematic Map of Risk*, and operative actions Local Authorities shall consider. The second issue, which regards the cultural status of societies, involve the *genius loci*, the specific preparedness of communities, and the awareness of local government alike. Then, the economic aspects cannot be underestimated, both in terms of capital spent at the beginning of any operation but saved over the long-term period, and in terms of job creation in many sector, at any stage of the development.

The fulfilment of all these aspects interwoven reduces the global and local level of risk. Evaluations commonly conducted on objects and sources of hazard alone rarely bring long-term benefits to one community. This is so because, in the light of quantum mechanics principles, as seen in Chapter 3.1.2, space and time are not seen as emergent properties of objects anymore. The intent of the *Telematic Map of Risk* is indeed to disjoint objects from their manifestation *a priori*, to reintroduce them into the city as spatio-temporal adaptive entities.

In fact, whereas the first master plan represent a traditional way of designing the city to come—albeit very flexible and accurate—the cluster plan methodology brought many challenging innovations. Cluster plans are in motion, and develop a networked instant city, rather than a wide variety of *micro-cosmoi*, or patterned settlements linked by similar features and approaches to the environment. In doing so, the city is developed as a whole body.

Since traditional master plans are static, they cannot represent the dynamism of change. They cannot either show dynamic behaviours or project the variation of spatial entities on rigid platforms. What comes out from the cluster plan is not a master plan (II), it is not intended as a plan whose criteria are going to be materialised in future, it must not be considered a programme for future actions on the territory. It is indeed the opposite: a photograph taken in the future of one of the thousands likely developments for the area, based on the indeterminacy of change. We will be calling it the 'Plan of Indeterminacy,' which shows that it is possible to develop a complex area with the principles brought by the cluster plan, the guidelines, and the relationships between spatial entities. Instead of being the plan to determine architectural developments, it is the evolving relationship between spatial features that shape the city to come.

The final design results in the awareness of being able to be innovated over time, as the reality is in a status of perpetual mutation. The city grows and develops itself through a self-organised capacity to adapt to change and discontinuities. 'A selforganized system must be always alive and without finalizing, since conclusion is another name for death.' (Stafford Beer, 1970) The solution is thus a temporal—and not temporary—result: adaptable systems anticipate steps ahead. They do so without being volatile, unsteady. Yet, they keep evolving in a state of total openness to variation.

Hence, the city of indeterminacy is driven by people's behaviours, through almost-real-time devices tracking, and by anticipation of future concausal phenomena (see Ch. 1.1.2). The collapse of the separation between digital domains and physical phenomena, caused by the *Telematic Map of Risk*, can be summed up in the following steps:

Step One:

open datasets & predictions
people's real-time geolocation > simulation model (on a GIS platform)

Step Two:

simulation model
guidelines > cluster plan

Step Three:

cluster plan
design process > plan of indeterminacy

Step One has governmental agencies and non-governmental bodies, and people who use GIS devices as main actors. The second stage involves the new figure of the architect 3.0, infrastructural engineers, and urban planners. Then, in Step Three all the professionals pin down in Chapter 3.3.1 concur to build a disaster-resilient environment.

The accomplishment of these stages represents a strong methodology

Plate 3.21
Plan of Indeterminacy.

aimed to guarantee the simplification of over-complex systems. Yet, as the plan of indeterminacy allows for a non-determined number of actions, an instable but coherent complex system arises. Since '[t]o say that something is complex means [...] that the number of its determinations is simply infinite,'[14] the interactions between water and people shall be varying over time. It changes as tide and water flow levels change, and it is also altered by the variation of people's behaviours as result of water dynamics.

Right as global warming generates a series of non-local feedback loops in the environment, operative actions aimed to lower the local level of risk produce benefits for their specific area, and possibly also for connected catchment sites. So, infrastructural and architectural variations change the level of risk both locally and globally, as the morphological aspects of the environment are changed. Changes on the natural and built environment cause variations in people behaviours too. In fact, as public and private spaces are re-shaped, a new series of human activities and spatial correlations arise.

Naturally, all these spatio-behavioural alterations lead to immediate changes on the *Telematic Map of Risk* as direct consequence. At-flood-risk areas can shift from a level of risk to another, due to geomorphological variations and infra-structural improvements. Also real-time people's location undergoes significant changes as soon as interventions on the territory become operative. Areas at risk shall be treated considering the network they can create upstream or downstream, depending on whether the flow is tidal or fluvial. To form a network means to operate with smaller interventions, which are more productive and less invasive than punctual ones. Moreover, the importance of lowering peaks on the digital map (see Plate 3.12, Ch. 3.1.2) is mainly related to possible congestion of public outdoor places and the infrastructure connected to these, in case of catastrophic event. Representing consistent clusters of people in areas with high level of risk, they are the areas where to activate strategic actions first—through the use of the guidelines—, since they can affect the adjacent areas too.

So the *Telematic Map of Risk* brings a solid loop of actions and reactions on the environment, beside the technological innovation regarding the use of real-time information for territory planning. Data provided by Agencies and non-governmental bodies, and cluster geolocation guide

[14] Bellut C., 2008, "Ach, Luise, lass ... das ist ein zu weites Feld," or: The Gordian Knot of Complexity". In Gleiniger A., Vrachliotis G. (eds.), *Complexity. Design Strategy and World View*, Birkhäuser Verlag AG, Berlin, p. 111.

redevelopments and new developments for the natural and built environment. These alterations determine sensitive changes on environmental models and human behaviours, which alter original datasets, and consequentially the digital map.

Sustainable operative actions for environmental improvements and communities' safety are often easier to be developed over the natural environment rather than the city. This is mainly due to over-complexity of infrastructures, and the widespread historical heritage. Infrastructures though can be developed in a much more flexible way, as we saw in the previous chapters. Hybrid infrastructures indeed facilitate interventions, and the gap between immaterial technologies and the real world tends to cease. To give networks of developments a priority of growth, as shown in Plate 3.20 (Ch 3.3.1), turns heavy infrastructural changes into plugins onto an existing system whose basic features remain unaltered.

Furthermore, also the state of the built environment highly influences territorial governance. Particular attention must be given to historical city centres, either in case of its being part of a technologically developed country or not. (Local political state influences considerably this question.) Historic heritage is often considered as a compact built area completed and permanent, while the rest of the territory allows change. Yet, the old town should be considered mutable as the territory, because it is part of the territory, ad it is subjected to the same threats. The conservative drift supported by the nostalgic of the Academia characterises a vast number of cities. Over the last century it has always been avoiding the city to evolve. But now the situation we are facing is radically different, as global warming is going to considerably change the way we live our cities. Hence, all the conservative prejudices have to cease when the issue is the survival of entire communities. This does not mean any detachment from conservation values. In fact, we shall not promote anything but the preservation of historic, cultural and natural heritage building and sites. Nevertheless, the safeguarding of these could be guaranteed through direct interventions, as explained in the guidelines (see Ch. 3.2.2 and Annex A).

City centres are changing in terms of communities and environmental context, so their anthropogenic settings cannot remain unchanged if hazards could undermine a number of people. Architects must understand the necessity to respond to future environmental issues before drastic changes happen. In this context, the aim of the guidelines is to instruct and advise people responsible of future developments and redevelopments, in order to drive the change toward an open range of future actions.

[14] "In German, a mnemonic can be fashioned from the literal meaning of the Latin word complicare. which means "to fold together (zusammenfalten)": the complicated, then, can be rendered graspable via unfolding (Entfaltung), because it thereby becomes simple (einfach) in a sense of naïve or ingenuous (einfältig). But the Latin word complexus means "mutual embrace," or, so to speak, the labyrinthine, the convoluted: here, simplicity already contains within itself the seed of all the complexity that comes to appearance through its own development. In cases of doubt, then, the complicated can be profitably reduced and simplified—but the complex, in contrast, cannot be simplified with impunity. To say that something is complicated means that the finite number of its determinations cannot be grasped directly. To say that something is complex means, by contrast, that the number of its determinations is simply infinite."

(Bellut C., 'Ach, Luise, lass ... das ist ein zu weites Feld,' or: 'The Gordian Knot of Complexity')

4 LIMITATIONS AND CONCLUSIONS

Low-tech and high-tech 4.1

We cannot consider the planning strategies developed in this dissertation (and design process in the widest sense) as if their only target would be to reach a concrete result to be built at the instant. Indeed, they have a broader scope, which does not mean being less tangible, even though it is partially immaterial. On the contrary, strategic planning process becomes much more sophisticated, because it is conducted through the complexity of city layers. This creates a dense synthesis of the reality, which leads to a complexity that is easier to be dealt with. Hence, the final design results in the awareness of being able to be innovated over time, as the reality is in a status of perpetual metamorphic and catastrophic mutation. The solution is thus a temporary result: the entire environment change—it is nature, it is the nature of cities. Infrastructural solutions in-determine the features of the built environment that, being based on flexible criteria, is adaptable. Consequentially, adaptable systems anticipate the steps ahead.

Flood anticipation is a crucial topic to build communities' resilience, sharing risk knowledge, and rising people's preparedness. The common understanding of flood risk is closely tied to governmental consciousness of local and territorial water dynamics. If prevention strategies on all scales are not promoted and advertised by authorities—although they ordinarily deal with water issues—, the commonalty is not made aware of political and territorial choices. Moreover, despite efforts are made in order to outreach cities' vulnerability, a lot more can be done to make the built and the natural environment capable of letting water being exploited, instead of being kept out. Territorial-scale management is easier to deal with, as state government experiences the entire range of catastrophes and disasters occurring in one nation. Regional authorities are lower hit; and local authorities even fewer. Because local governments experience fewer hazards, they are often not particularly sensitive to important risk issues—at least until they are hit. This is the reason why massive engineering infrastructural works are more likely do be implemented, whereas diffused works on the natural and built environment are rarely achieved, and local authorities usually pay less attention for them.

Politics wise, the Department for Environment, Food and Rural Affairs (DEFRA), responsible for environmental protection, works in synergy with county councils of the Lead Local Flood Authorities (LLFAs), local authorities (in the case of Greater London, the Greater London Authority), and the Environment Agency (EA). The EA, a non-departmental public body, provides real-time flood warnings and river levels.[1] Nathless, even though rivers' status and flood alert are provided real-time, this information is disconnected to any strategic planning process. In fact, they are more focused on long-term general projections, which of course are not based on local assessments. This causes important discontinuities between design and real phenomena, creating mass opinions and fashion-related actions rather than operative common strategies.

Covering the three scales highlighted in Chapter 3.1.2, the *Telematic Map of Risk* connects projects developed by architecture companies to governmental strategies. Departments of the Built Environment are the main **stakeholders** of the new platform, promoting building design strategies that reduce the impact of developments on the environment, and working in order to ensure low risk of flooding. Despite the useful information provided by these departments of the local authorities, a networking vision for future sustainable actions is still missing.

stakeholders *are, for the aim of this research, all those Depatments working in synergy with Agencies and Councils to guarantee the success of innovative systems for strategic urban planning.*

Promoting that local plans should take into account the environmental change due to global warming, the *National Planning Policy Framework* (DCLG, 2012) assert that '[w]hen new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures, including through the planning of green infrastructure.'[2] It is also confirmed the sequential, risk-based approach of the *PPS25* (see Ch. 1.3.2), in order to reduce flood risk to people and properties. Moreover, the LLFAs are indicated by the

1 http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683.0&y=355134.0&scale=1&layerGroups=default&ep=map&textonly=off&lang=_e&topic=floodmap&utm_source=Poster&utm_medium=FloodRisk&utm_campaign=FloodMonth13#x=526712&y=170726&lg=1,2,10,&scale=4

2 DCLG, 2012, *National Planning Policy Framework*, Crown copyright, London, par. 99, p. 23.

Flood and Water Management Act (2010) as the Authority for developing, applying, and monitoring strategies for local flood risk management 'in their areas'.[3] This means that even though the organisational pyramid is properly working in terms of bureaucracy system, from the operative point of view it lacks of effective collaboration between boroughs. This is demonstrable by looking at any of the *Local Flood Risk Management Strategy Action Plan*, which is mainly based on programmes and references to best practices. The imitation of best practices is helpful on the short-term, while on the long-period it misses the main perspective i.e., the adaptive relationship with the environment. Furthermore, it limits studies of new infra-structural systems capable to lead to technological transfer and innovations in the disciplines analysed in Chapter 3.3.1.

In the light of these considerations, the use of the *Telematic Map of Risk* by local authorities and non-departmental public body would fill the gap between programmes and actions. This is allowed by connecting the map to the natural and built environment through the cluster plan (Ch. 3.3.1) and the guidelines for future developments (Ch. 3.2.2). Having a global tool for the control of the territory, architecture practices shall work in tight connection with local authorities, and their work verified by the competent Authority, using the same methodology. Indeed, architects shall be provided not only the guidelines, but also the telematic platform to comprehend the territory, and validate their design process.

prerequisites *must be evaluated and constantly updated for the definition of the a priori condition to create a valid digital tool.*

Yet, to be operative the *Telematic Map of Risk* needs few **prerequisites** necessary to reach a minimum level of information. Taking it for granted that the normative systems work properly towards environmental care and disaster-resilient communities, and that technological advancements are increasing people's data, the issue mainly regards the natural and built environment. To talk about the natural environment does not just mean to accurately know terrain height information, but also meteorological and water courses' digital data. The landform is instrumental to determine the levels of risk related to tide water, and to analyse watercourses' flow dynamics. This lead to a highly accurate analysis, which is not based on historic data, but on future projections. A nearly equivalent precision could be obtained through analogue data of historic ground measurements of height but, again, avoiding the use of maps tracing the area reached by water over the past centuries. Also rivers' data and information play a crucial role for the complete comprehension of water phenomena. They are often provided as real-time or almost real-time open datasets, easily usable

[3] Flood and Water Management Act 2010, Act of Parliament, Crown copyright, p.10.

by any user. These requirements are sufficient to form a comprehensive overview of the phenomena. Hence the repeatability is guaranteed by the qualitative level of data that is reached—still intended as rough material. That is, if that necessary and sufficient data can be collected, the *Telematic Map of Risk* can be completely filled in, and design process can take full advantage of the innovative platform.

The necessity of reaching these requirements opens two different conditions i.e., the applicability of the *Telematic Map of Risk* only for the technologically developed countries. Thus, the methodology argued in this dissertation cannot be applied to those countries or cities whose governments and local authorities have not invested in a basic data-gathering system. Yet, this exclusion could be only temporary for a number of countries, for the very narrow the gap they have to fill. The repeatability of the process depends on digital infrastructural system, and the political organisation of territories challenged by any source of a hazard.

In case of technological gap, in terms of measurement devices, it is firstly necessary to identify crucial point of survey, capable of providing a complete view of water dynamics. To determine these points, the *a priori* knowledge of watercourses' flow phenomena is crucial. Survey stations have to be located in strategic position, and possibly in correspondence of other infrastructures or Agencies, so that data gathering can be simultaneous. They must disclose information that is not seen trough direct observation. For instance, the three surveys of the case study (Teddington Lock, Richmond, and Silvertown, see Ch. 2.1.2) have been chosen to evaluate water flow rates and water levels in sequence. The first section is from a lock to another survey station where the estuarine tide flowing upstream is in contemporary presence of downstream fluvial tide; the second one reaches the barrier that regulate estuarine tide flows.

("The *Directive 2007/60/EC* on the assessment and management of flood risks [...] requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. With this Directive also reinforces the rights of the public to access this information and to have a say in the planning process.")[4]

As a matter of fact, another problem can be faced by data analysts that

[4] *Directive 2007/60/EC of the European Parliament and of the Council* of 23 October 2007 on the assessment and management of flood risks. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007L0060

is, the real-time availability of data and not just its availability. In fact, often data are collected and archived, instead of being transformed into usable information. When this happens the lack can easily be solved in terms of Internet policies. If data are not treated as open raw material, further studies can hardly be conducted. Indeed, if data or information remains confined within governmental and autonomous agencies, data analysts are not able to create correlations between different datasets (Ch. 2.2.1).

Whereas private agencies rarely make full data available, Local Authorities and non-departmental public bodies provide detailed datasets from which any public user may access. In order to show different levels of open data developments, three cities are compared in Plate 4.1. These are Genoa (IT), London (UK), and Boston (MA). Each one of these cities daily deals with water management and use, and has (or has not) different strategic plans to cope with challenges due to climate change and sea level rise. The aim is to analyse differences in terms of digital—and, in a second instance, analogue—data availability.

Data and information concerning water, the landform, communities, the built and natural environment, etc. are easy to be collected on the Internet, as evident from the previous chapters. The city of Boston represents one of the most advanced beacons of data gathering and information sharing. On the governmental open dataset *BostonMaps: Open Data*[5] a wide variety of tables, charts and data can be even directly set onto ArcGIS maps. Technology is used to make government records available to the public, which can individually work on this interoperable data, and also create networks with other developers. These datasets have such visual qualities that information is extremely easy to be understood from the most. On the other hand, the case of Genoa's open data website[6], is a daedal of links leading to .cvs files that provide references to maps, instead of maps themselves. Moreover, these references are not geolocated and, most of all do not regard any environmental issue.

The analysis of Plate 4.1 is aimed to support the case study of London as one of the many fields of applicability. It comes out undoubtedly how data determines the typologies of actions, and the quality of strategic programmes. The comparison shows how the distance between the level of technological development in one country is not perforce directly proportional with the proximity to a disastrous event. Rather, it is a so-

5 http://bostonopendata.boston.opendata.arcgis.com/
http://maps.cityofboston.gov/ArcGIS/rest/services/CityServices/OPEN_DATA/MapServer

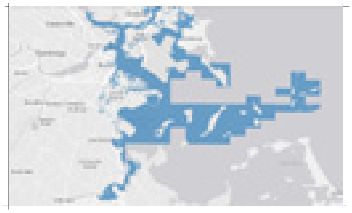
6 http://dati.comune.genova.it/en

BOSTON

TERRITORIAL

River&sea’s dynamics comprehension

data fully gathered

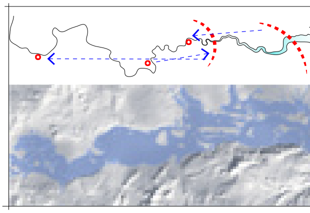


Tide & river control flash flood management

The City of Boston has engaged the Metropolitan Area Planning Council (MAPC) to update the City's 2008 Hazard Mitigation Plan. This Plan presents a strategy for reducing the City's vulnerability to the impacts of natural hazard events such as flood and hurricanes

River&sea’s dynamics comprehension

data fully gathered



CITY

Areas definition is strictly connected to damages

data fully gathered

Tide control

All areas where future growth is expected are within a number of hazard zones

The shift from insurance perspective to a preventive point of view is needed

Definition of water boroughs

data fully gathered

HUMAN

Evaluation of local level of risk

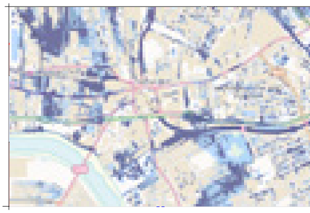
data fully gathered

Tide control

Comprehensive Emergency Management Plan (CEMP) – Every community in Massachusetts is required to have a CEMP. These plans address mitigation, preparedness, response and recovery from a variety of natural and man-made emergencies

Evaluation of local level of risk

data fully gathered



TOOL	ACTIONS (prevention)	TOOL

Plate 4.1
Open data availability comparison between Boston, London, and Genoa.

LONDON | GENOA

Tide control

Thames and planned Estuary Barrier under engineers competences for tidal water management

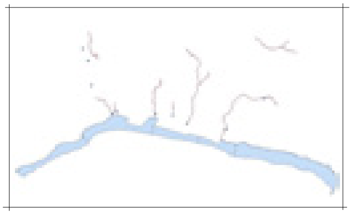
River and groundwater control

Territorial cognisance of water paths and identification of areas at risk of flood

Flow and water levels monitoring over the survey stations

River&sea's dynamics comprehension

data missing



River control

Territorial cognisance of water paths and identification of areas at risk of flood

Flow and water levels monitoring over the survey stations

Infrastructural & structural interventions for areas at risk of flood

Eg. Genoa, very few digital data and uncomplete .pdf maps

Tide control

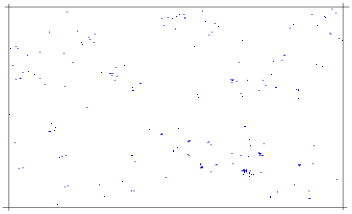
The telematic map of the risk is help in defining boundaries of flood risk between countryside and cities

River and groundwater control

Cognisance of how water paths and people are defining new territories with different hazard conditions and needs

Alerting people

data missing



River monitoring

Provide any river and canal monitoring devices in order to steady oversee water level and flow variations

Use of GIS system to geolocate people within a certain area of risk, in order to communicate safe location to go to in advance

Time takes a central role, as alerts come from scientific forecasts and not humans' suggestions - working on people's behaviour

Tide control

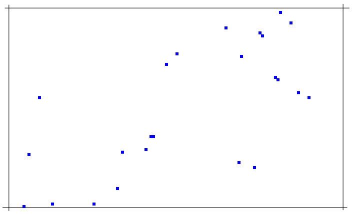
Infrastructural & structural interventions for areas not protected by the Thames Barrier (and by the Estuary Barrier in future)

River and groundwater control

Multifarious structural preventive interventions varying depending on boroughs, the level of risk and the expected lifetime of buildings

Evaluation of local level of risk

data missing



River and groundwater control

Structural interventions at the building scale

Mandatory guidelines for new buildings, refurbishments, and restorations

Eg. Genoa, flood risk assessment is evaluated on previous disastrous events

ACTIONS (prevention) | TOOL | ACTIONS (alert) cio-political issue. It depends on the awareness of the commonalty, and the propensity of governments in spending more now for a larger benefit in future. All in all, the most dangerous limitation that causes low-tech countries' carelessness is the political delay in recognising threats and rise social awareness of the risks one community is subjected to. Recovery strategies often take the place of preventive actions; thus, it is a matter of time, and communication.

Time and communication in the design process 4.2

Anticipatory strategies base their actions on reducing specific risks before events' occurrences i.e., preventing the catastrophe becomes a disaster (see Ch. 1.1.1). Advancements in technology, which have always been the engine of human evolution over the millennia, do help societies in identifying, assess, and manage local risks. To believe in progress is a human duty: it challenges people to discover new territories. Yet, the mere faith in progress does not necessarily lead to evolution. Being conscious that the term «evolution» implies a direction—and indeed it has its opposite, «involution»—, technological progress may cause the regression of one society. The critical factor is the level of complexity, as seen in Chapter 3.1.1. In fact, new technologies and new devices have to carry into communities improvements for infrastructural systems. Whether this does not happen, progress imposes more restrictions than new possibilities and challenges. When the restrictions concerning computers' domination over human beings are not accepted, 'progress itself and our fight against the increase of **entropy**'[7] cease. On the other side, the opposite risk is to not perceive the importance and scope of progress. This refusal or denial inevitably causes involution, as the direction of progress is rejected. However, technological progress needs to be operative in the physical world.

entropy *is, in data transmission and information theory, a measure of the loss of information in a transmitted signal or message.*

New challenges posed by current digital technologies and communication systems have rarely produced architectural outcomes in terms of water management before, during, and after any flood event. New technologies tend to become obsolete quite fast, because of global demand and availability. Demand fosters research, and availability rises data sharing. Besides, more people are also autonomously involved in innovative tech-

[7] Wiener N., 1950, *The human use of human beings. Cybernetics and society*, Da Capo, U.S.A., p. 42.

nologies design, with consequent technological transfers. So, the complexity of real world is mitigated by exchange of knowledge and skills, which connect and interweave many different realms. Architecture must always be the avant-garde of societies, because it moulds the environment where communities are settled. Yet, the more architects believe that new technologies run faster than architecture, the more likely architectural technology is to become obsolete.

The flexibility and adaptability of cities that shall derive from the use of the *Telematic Map of Risk* represent a radical choice in changing the point of view of architectural innovation. In fact, as the proposed planning strategies require ICT systems to create city's infrastructures, the gap between architecture and technology is necessarily filled. Since one depends on the other, the vulnerability of digital technology—in terms of updating before its decay—can be neither higher nor lower than architectural obsolescence.

Dealing with risk, the built environment can respond in two different ways to catastrophic events. The first case regards the adoption of **anticipatory strategies** to control water. The guidelines provided in Chapter 3.2.2, aimed to foster flood-resilient communities, highlight the importance of connective systems for the urban fabric. In the second one, socio-political conditions do not enable **preventive design actions**. In this case the built environment fundamentally acts as shelter to protect people whose dwellings and workplaces are exposed to hazard within the FWAA.

anticipatory strategies—*infrastructures and processes necessary for anticipatory actions — vs* **preventive design action**—*structures and devices necessary to lower the extent of losses.*

Geospatial analysis can provide substantial contributions in identifying safe areas. As seen in Chapter 3.3.1, the *Telematic Map of Risk* allows for the calculation of the mean centre and the standard deviational ellipse for a specific area of analysis. Since almost any city is able to provide digital maps of the built environment, and it is also possible to geolocate people through their posts, one can achieve to investigate peoples' distribution on the territory even in technologically underdeveloped countries. So, governmental agencies and non-departmental public body shall be able to identify strategic structures close to the mean centre point calculated on the *Telematic Map of Risk*. Depending on the concentration of people within a certain area, which is identified by the ellipse, the most adequate public or semi-public structure can be chosen as shelter for areas at risk. This possibility highlight that the limits of the innovative mapping process consists principally in dealing with the design process, rather than the tool itself.

A second step that can be pursued regards the way to communicate people the closest safe area. The Environment Agency is responsible for warning people of the risk of flooding from rivers, groundwater, and the sea. Alerts are given divided by region (Anglian, Midlands, Northeast, Northwest, Southeast, Southwest, and Wales)[8], and then locally, according to four levels of risk: Severe flooding, Danger to life; Flood Warning, Flooding is expected, immediate action required; Flood Alert, Flooding is possible, be prepared; Warning no longer in force, Flood warnings and flood alerts that have been removed in the last 24 hours. The Environment Agency provides warnings by phone, text or email through the service *Floodline Warnings Direct*. This alerting system, albeit an important one, is not considering individual positions though. Here the contrast between personal devices—and thus personal information provided—and generic information rises. It means indeed that ICT and GI systems are not perfectly integrated yet in our societies. Although efforts are being made to outreach digital information's obstacles, more can be done to make it more accessible.

The advancement of any society can be comprehended through the study of digital systems, and the communication devices that belong to the field of digital communication. Its output is the information provided to the community, whose quality is crucial for the understanding of the message, and consequently for people's behaviour. Messages and appurtenant information exchanged with the outer world are usually emitted by machines, and terminate in a specific 'machine' known as the human being. It is a particular exchange of information, since one instructs and orders, while the other is instructed and ordered. Information regarding risks often needs an exceptional care, for the condition of urgency that could involve both the source of information, and the recipient of it.

Communication addresses its messages in three different phases i.e., before, during, and after a catastrophic event, and before, during, and after a disastrous event. So, the time before a natural-anthropogenic phenomenon (see Ch. 1.1.2) can be characterised by preventive actions or simple alert, depending on the level of awareness and technological innovation. Similarly, the very moment of the event can involve a community as passive party or allow it for studies and analyses of the necessary improvements to come. The same distinction, then, have to be made for the period between a catastrophic event and another: an unprepared society would be focus on the count of the losses and the organisation of the reconstruction, while a prepared community may keep strengthening its resilience in the smartest and most innovative way.

8 http://apps.environment-agency.gov.uk/flood/31618.aspx

Social evolution is grounded on the factors of stability that distinguish one community. These generally last for a long time, so that any other shorter event is perceived as a temporary condition or something that destabilise the social order. Yet, when catastrophic events are extremely frequent, albeit occurring for a short period, they tend to be perceived as continuous. When their frequency lasts longer than ordinary periods, the moment of crisis of a natural-anthropogenic event can be hardly outreach. Entropic states bring losses in order and management of complex systems. This condition caused by social unpreparedness generates an entropic pressure on the territory during the pre- and post-disaster period. Temporary solutions take over steady socio-environmental conditions, disconnecting new developments to the *genius loci*, which is even more crucial during calamities. These situations are felt as permanent status even though they do not bring any stability by themselves.

For such reasons, the challenging role of architecture can be deducted. Architects operate in evolving scenarios characterised by instability and uncertainty. The indeterminacy of future though shall give strength to the *Telematic Map of Risk*, as it is based on changing scenarios. Whereas the common thoughts support the equivalence 'permanent equal to stability', it is now clear that the opposite is true, considering catastrophic phenomena. Permanent solutions are neither flexible nor resilient, which does not mean that we are going to necessarily live on boats or floating houses to prevent flood aftermaths. It means that the whole city must be flexible in the use, and the adaptation process will not be defeated by any catastrophic event.

Future scenario of research 4.3

1. In this dissertation flood risk was considered to refine the *Telematic Map of Risk*, from the initial idea to the final outcomes. The choice of one of the most preeminent hazards for our cities was not intended though as a limitation to the general idea of risk. On the contrary, the identification of one of the many sources of risk helped in giving the digital platform a specific purpose. That is, switching from intangible realms to the most material one, the city.

The main extension of this thesis regards other typologies of hazard, and related risks. In fact, the *Telematic Map of Risk* can be adapted to different catastrophic events. The levels of risk determined by the mere source of the hazard shall take the place of the flood ones, and people's geolocation could be changed with another set of information on the map. Naturally, the guidelines shall be changed with technological solution that respond to the new phenomenon, keeping the same degree of flexibility both in term of correlated solution and spatial relation to the territory. The aim of the cluster plan is going to change as direct consequence, even though the process to generate it remains the same. New professionals shall be involved over the design process, being taken on *architects 3.0*, geoanalysts, data analysts, anthropologists, engineers, risk managers, and economists.

2. As highlighted in Chapters 4.1 and 4.2, the innovative digital map explained in this dissertation works when a specific qualitative and quantitative standard of data is reached. For those countries whose datasets lays below that level, the *Telematic Map of Risk* cannot work. Implemental upgrades in data gathering and datasets opening can often be achieved with just little efforts. Otherwise, in case of adverse political-economic situation, preventive actions may be replaced by alerting strategies.

Yet, even alerting systems need some preventive actions, which can be divided in structural and infrastructural issues. In terms of structural operation, safe areas and buildings must be identified and brought into compliance as regards the identified risk(s). On the other hand, infrastructural issues concern the way people are alerted of danger. In this perspective, cluster studies conducted on *ArcMap* for flood risk can be very helpful in trying to develop applications for mobiles, tablets, and other digital devices aimed to guide people before and during a calamity. To identify people's location and suggest them reliable routes, and safe places for their security is a profitable scenario easy to gain. A number of configurable web applications for telematic devices offer various functions, such as different layouts, tools, and so forth. Web application makers such as *Edina*[9], *Appery.io*[10], *Google Maps APIs*[11], etc., starting from map viewers, allow for the configuration of components. Once a programmer has defined the platform for one source of risk, this shall be tested and expanded to other hazards changing components and datasets.

These telematic devices and punctual interventions on safe areas and

9 http://doc.arcgis.com/en/web-appbuilder/

10 https://devcenter.appery.io/

11 https://developers.google.com/maps/?hl=en

buildings shall be associated to large infrastructural works and reduce the extension of negative aftermaths and losses.

3. The third challenge the outcomes of this dissertation open regards innovation in computer modelling. Digital modelling reduce time and cost, enable rapid generation of design strategies, and improve the accuracy of models themselves—resulting in significantly better performing buildings. Materials use can be rationalised thanks to BIM software, and energy consumption can be lowered through accurate building energy models that go far beyond traditional design process.

As technological developments bring great benefits to building simulation, the spectrum of analysis is going to be increasing over the next few years. Building design has been tightly connected to BIM (Building Information Modelling) systems, which brings together all of the information regarding each component of a building. Complementary to BIM software, BEM (Building Energy Modelling) systems help to raise buildings efficiency, assessing building performance through simulation. BEM software helps with general building design, to reach standard energy performance; with life-cycle cost analysis, comparing diverse design strategies; and energy retrofit analysis, predicting savings associated to proposed interventions.

Typical energy models have inputs for climate. Yet, global warming is bringing changes not only on the magnitude of phenomena, but also on consequences on the territory. New software connecting the *Telematic Map of Risk* can be developed withe the aim of implementing buildings performances, and change the design attitude to global phenomena. The definition of the series of guidelines shown in this dissertation shall be the bridge between natural-anthropogenic events and urban developments. As environmental data are introduced into the calculation system, data deriving from risk analysis should be associated to all the other inputs that contribute to the design process.

The rising threats that will be involving our communities over the next decades shall encourage and inspire developers, planners to try and find new ways to attenuate the aftermaths of catastrophic events. Only a prompt technological tackle that focuses on preventive actions on the territory will avoid design process to fail in its only purpose, i.e., to create people's places.

All in all, this dissertation focuses on the relation between many different innovative approaches to the common ground that link each society. That is, the way human behaviour determines precise life conditions and establishes a certain kind of dialogue with natural and environmental phenomena. As direct consequence, if this balance is not kept under control, natural events have negative effects on the territory, causing our communities being under unpredicted fluctuations of global events. A brief synthesis of all the innovative aspects achieved throughout the doctoral studies is summed up, as follows:

- Correlation between water dynamics in floodplains and people's spatial behaviours within the Flood Warning and Alert Areas (FWAA);

- The Telematic Map of Risk is a four-dimensional tool that allows for the assessment of changing events and behaviours;

- Master plans cannot exist any longer, since they project a static environment within an 'hyper-object' in motion, and they are replaced by flexible cluster plans;

- The analysis of all the professional figures involved in the strategic planning for the design of disaster-resilient cities creates new relationships between different sectors.

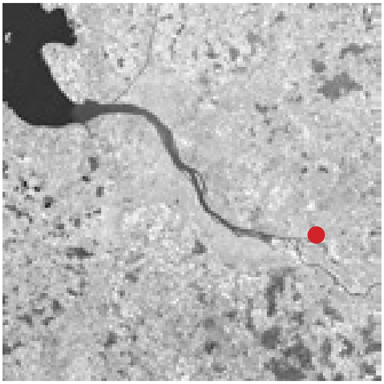
APPENDIX B

A_B1. Resilient communities: few samples

This first Section is an extension of Annex A. While the guidelines show typological approaches to architecture and urban planning, the aim of the examples that follow is to demonstrate how the guidelines can be combined and translated into practice.

The site analysis is associated to the guidelines of Chapter 3.2.2 and Annex A in an inverted process that extrapolates specific design tools utilised during the development of each project.

Particular attention must be given to the water-resilient developments in Hamburg, Germany; Wörth am Main, Germany; Zaragoza, Spain; and Choisy-le-Roi, France.



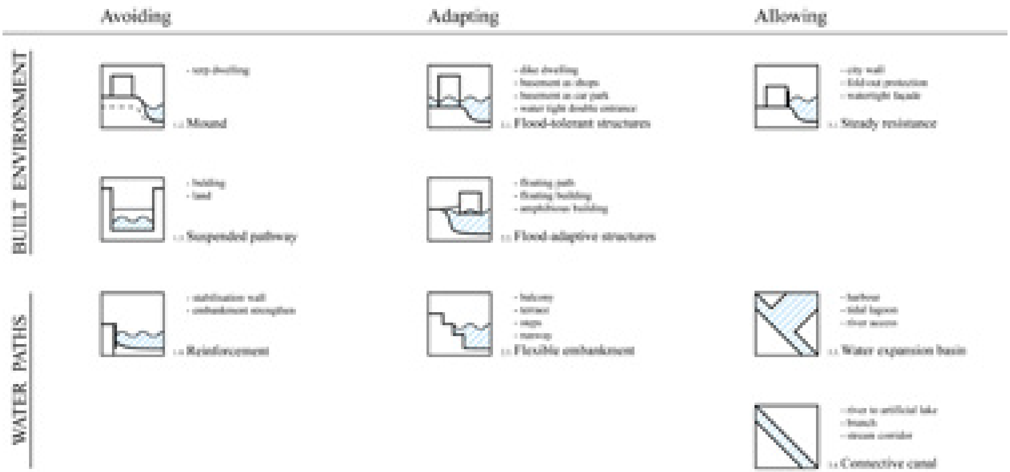
HafenCity
Hamburg, Germany

highest water level registered: 6.45 m.s.l.
catchment area: 140,000 km^2
mean discharge: 750 m^3/s
cause of flood: tidal fluctuation
design team: KCAP + ASTOC
redevelopment dimensions: 153 hectares
year: 1999 onwards

Hamburg has been undergoing Europe's largest inner city development project. HafenCity is a new urban district surrounded by the River Elbe and canals on all sides. By the first quarter of the 21st century it will be providing new homes for up to 12,000 people, and create 40,000 new jobs. The project has the potential to extend the town centre, creating a stronger connection with the Elbe. Eight new district sectors are planned in the original master plan. Their realisation is realising from west to east, and from north to south.

'Masterplans are often overtaken by events within a short space of time, and the quality can no longer be controlled. This informed the decision to opt for a combination of fixed basic principles and operationally manageable rules. The design process involved testing how various combinations of these guiding principles and rules would react to different urban planning structures, programmes, densities and growth prognoses. The results provided a wealth of information for development of concrete spatial designs.' (KCAP)

For being built outside the dike ring, in HafenCity buildings are artificially raised 8 metres above sea level, on concrete mounds. This will prevent them to be flooded even during the most severe events. Basements are not affected by normal tide, and they house car parks and small cafes facing the wide promenade. In case of flood they are sealed off by temporary waterproof protection elements. Also bridges, which lay at 7.5 meters—the protection limit—, are not vulnerable to flood events. These, creating an adaptive network with floating jetties, ensure HafenCity to remain connected to the town centre.
The districts the area has been subdivided in have been assigned specific qualities and limitations. Their diverse functions, in combination with a flexible set of rules, guarantee the highest freedom for architectural design. Beside that, the preservation of the old port layout provides a tighter connection of the site.

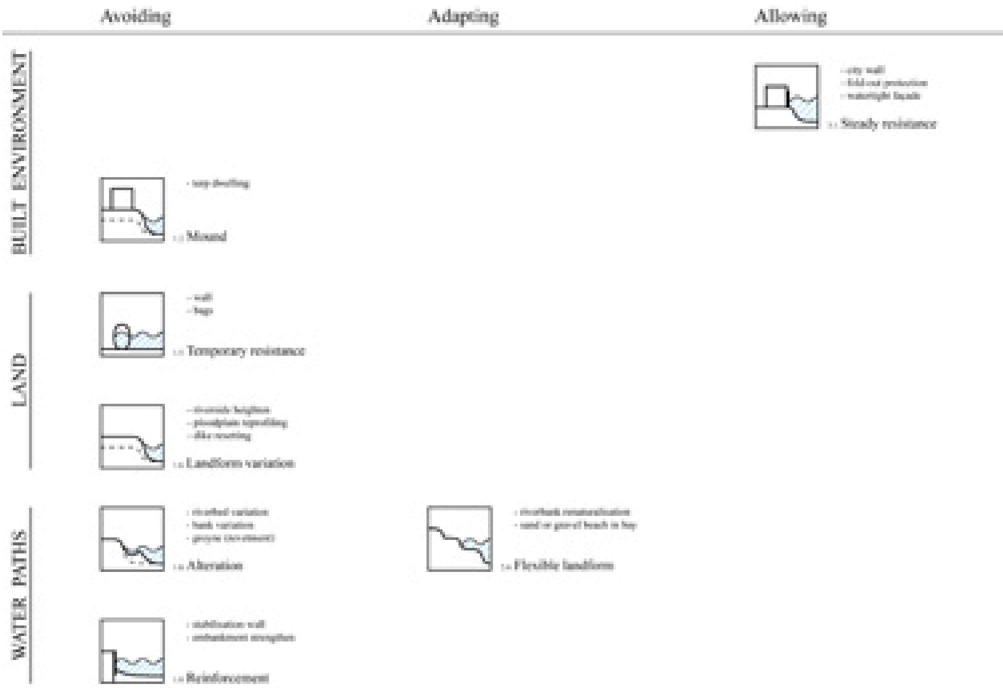


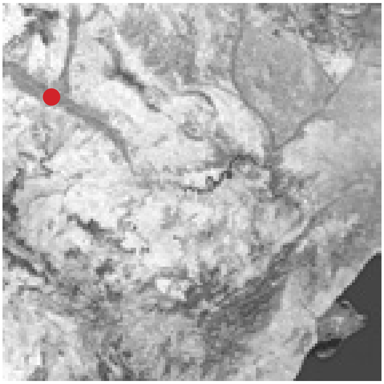
Avoiding
Adapting
Allowing
BUILT ENVIRONMENT
WATER PATHS
Mound
Flood-tolerant structures
Steady resistance
Suspended pathway
Flood-adaptive structures
Reinforcement
Flexible embankment
Water expansion basin
Connective canal

Wörth am Main
Bavaria, Germany

highest water level registered: 8.57 m.s.l.
catchment area: 21,600 km^2
mean discharge: 100 m^3/s
cause of flood: river flow
year: 2001

The increased number of flood events, and consequential rise of costs for heavy losses and damages, led many cities and towns on the River Main to put in actions operative strategies aimed to create a flood-resilient environment. under the Action Programme 2020 framework, sophisticated analytical and preventive systems has been established. Beside the creation of upstream retention areas, a number of vital infrastructures ahve been realised. For instance, monitoring and warning devices have been associated to solid flood walls, temporary barriers, and dikes. The strategy around this river is clearly focused on the creation of a functional network that is capable to connect and make diverse typologies of preventive measures more productive.
Undoubtedly, the main challenge posed by the project in Wörth am Main is the reconciliation of a medieval town protected by its walls, and contemporary needs. By 2001 the protection of the old town was raised to the probability of one-in-100-year floods.
For being on a low crest, and facing the riverbank, Wörth am Main had been a town easy to defend and given over to commerce and trade. From the severe flood occurred in 1882 and a second one in 1970, many citizens decided to leave the town or to move on new additional settlements, the so-called «Wörther Neustadt». As a direct aftermath of people leaving the old town, many social problems have arisen, and a number of buildings have been left abandoned. To isolated flood-defensive improvements started in 1985, a strategic extensive water management plan completed in 2001 brought long-term stability to the old town. The connection between the original settlement and the river is re-established again. The main work consists in a 3-meter-high reinforced concrete wall that reaches the same flood protection line of the upper part of the town. Where possible, the barrier has been kept on the inside of the historic wall, in order to guarantee the visual preservation of the listed building from the outside. The long advance flood-warning period has also allowed for the use of temporary barrier aimed reducing the visual impact on the main views. Moreover, a massive reinforcing underground concrete structure was realised.


Avoiding
Adapting
Allowing
BUILT ENVIRONMENT
Steady resistance
Mound
LAND
- wall
- bags
Temporary resistance
Landform variation
WATER PATHS
Alteration
Flexible landform
Reinforcement



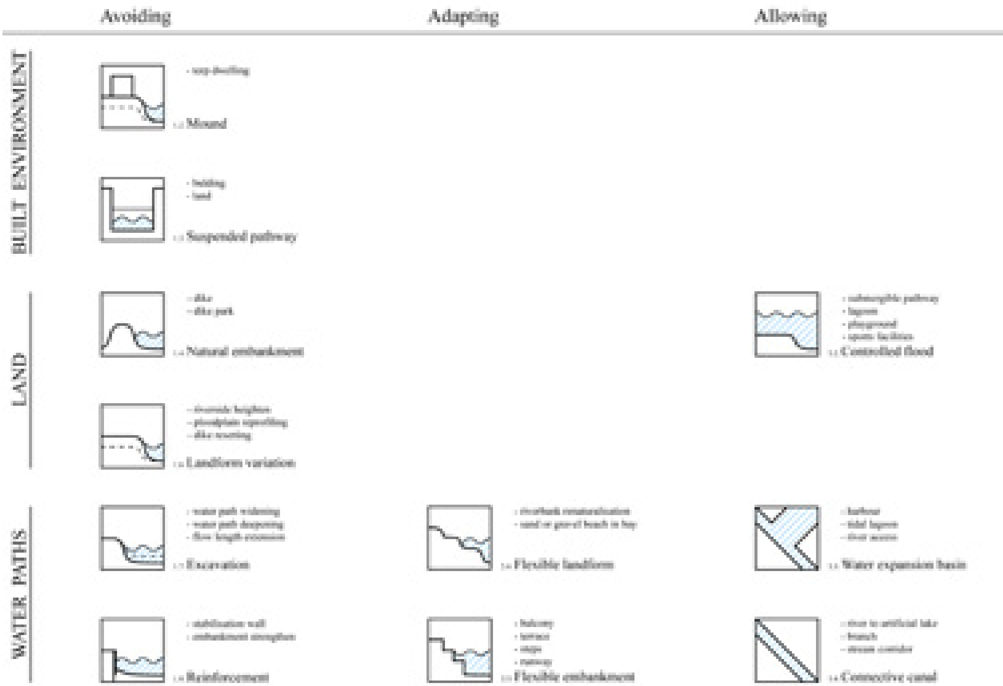
Zaragoza, Parque del Agua
Aragon, Spain

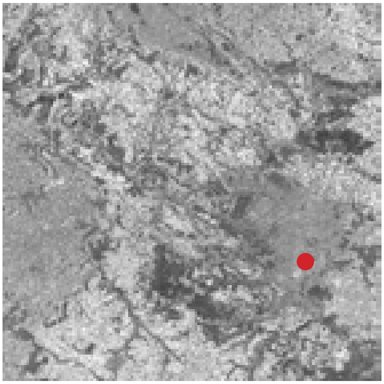
catchment area: 40,400 km^2
mean discharge: 267 m^3/s
cause of flood: floodplain
design team: aldayjover arquitectura y paisaje
year: 2005-2008

The 2008 Expo in Zaragoza, whose theme was 'Water and Sustainable Development,' the exhibition area was intended to reconnect the agricultural land irrigated by the River Ebro to the *hinterland* of the city. On an urban scale, the leading role of water has been enhanced by the creation of several new bridges and a water park.

'The imagined history to invent the park is to project ourselves on the silver forest of origin, to expand and settle there, cutting clearings, installing grassland, organizing the layout of the water as the farmers did. [The] ambition is not to establish a brutal picture on the site but allow the soil to express itsqualities:unlike architecture, the landscape is not drawn;it expresses the story of a territory and the relationship its inhabitants maintain with it. But even before, the bend belongs to the river, providing overflow space and natural filtering through the vegetation, sheltering only the most delicate areas.
The alluvial forest has been reduced, through centuries, to make room for agriculture. The Park returns much of the surface of the riparian forest bend, in which is now accentuated the silvery palette of vegetation that covers the rest of the park.
[The Water Park] organizes a living system, a journey that purifies water from the River Ebro, the Acequia del Rabal and the water table to bring itclean for recreational use. At the end of its journey, some water is recycled for irrigation and some is returned to the river through infiltration lagoons inserted between tamarisk fields that condense a rich wildlife.' (Aldayjover arquitectura y paisaje)

Aimed to demonstrate different ways of water use, the park is characterised by a network of canals, lagoons, and large pools. These, together with the surronding dike, control those areas that get flooded during severe events, and preserve those that are planned not being subjected to floods. Water treatement basins within the park are sealed off during flooding, in order to avoid contaminated water to nullify the natural purification process of the park.

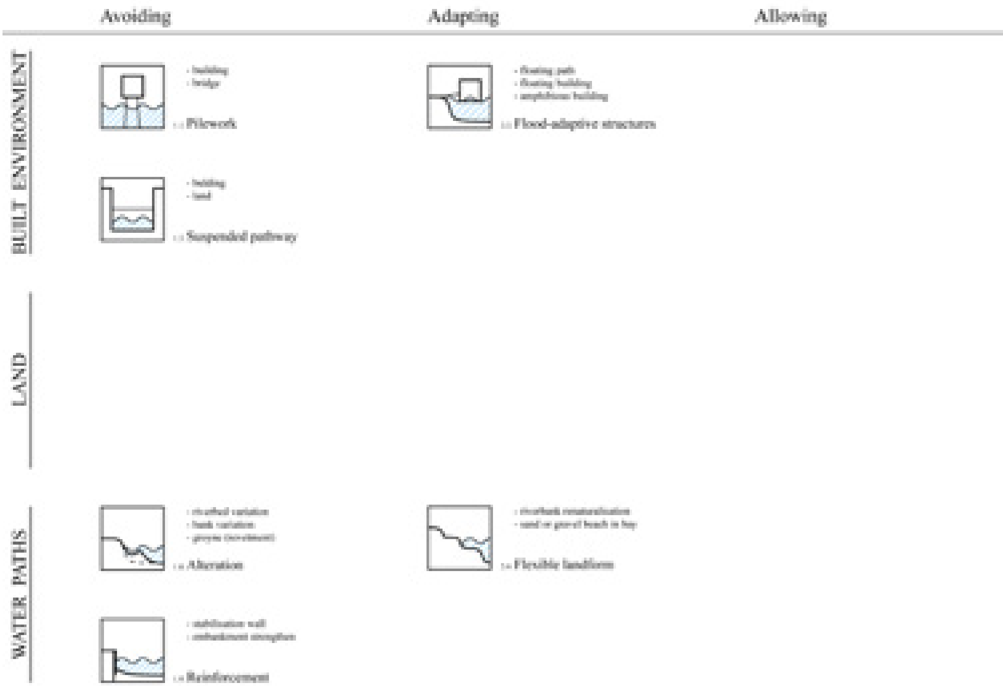

Avoiding
Adapting
Allowing
BUILT ENVIRONMENT
LAND
WATER PATHS
Mound
Suspended pathway
Natural embankment
Landform variation
Controlled flood
Excavation
Flexible landform
Water expansion basin
Reinforcement
Flexible embankment
Connective canal



Choisy-le-Roi
Val-de-Marne, France

catchment area: 30,800 km^2
mean discharge: 215 m^3/s
cause of flood: river flow
design team: SLG paysage
year: 2009

The encouragement to look after and redevelop degraded and underdeveloped areas of the city has been highly promoted by the *Région Parisienne*, ‘Paris Region’. The programme proposed by the Department Val-de-Marne has been put into practice in Choisy-le-Roi, with the riverside promenade *‘Quai des Gondoles’*, on the River Seine.
In this densely populated area, the embankments had been disconnecting the river to the town and the many activities carried out both in private and public sectors. The design of the promenade not only protect Choisy-le-Roi against a one-in-fifty-year flood, but also aims to give residents back the access to the Seine, and public amenities on the river.
Dividing the riverside into two levels, the river is accessible through a shore below the flood-safe level that connects it to the wide boardwalk on the new bank. The lower terrace sits on a steel frame anchored underground, which allows for a water-resistance performance. Moreover, some jetties and vegetated shores complement the deck. Temporary barriers are designed to close openings in the embankment that guarantee the access to the lower platform through steps.
The design of the new bank has been associated with a number of complementary protective measures that ensure the built environment not being damaged by the destructive force of water. At the same time, the flow of the Seine is only subjected to little changes during flood events. The existing embankment has been consolidated with steel beams, on the top of which a new one-metre-high waterproof wall has been built. A sheet pile retaining wall—used in soft soils and tight spaces—has been slidden underground, below the lower deck, in order to protect the structure from sediment erosion. Moreover, natural protection to the bank is offered through dense roots by a variety of local plants, which are being planted along the shore.
Care for the ecosystem is always a crucial aspect of any riverside renovation. Indeed, shores and offshore rocks alongside the Seine slow down the flow, and vegetation and animals can found a more suitable habitat.


Avoiding
Adapting
Allowing
BUILT ENVIRONMENT
Pilework
Flood-adaptive structures
Suspended pathway
LAND
WATER PATHS
Alteration
Flexible landform
Reinforcement

A_B2. Water data collection and models

The tables are processed from *http://environment.data.gov.uk/flood-monitoring/archive*, published by the Environment Agency, the Government Digital Service.

Hydrometric data including river levels and flood rate are gathered from stations around the United Kingdom using automatic field devices, usually every 15 minutes, and transferred via telemetry to internal and external systems in, or close to real time.

For this dissertation, the Thames is analysed at Kingston (Teddington), Richmond, and Silvertown.

All readings are in Greenwich Mean Time, all year.

The attributes of the tables are specified as follow:

Time: Time of Measurement;
Station reference: Reference based on combination of letters and numbers;
Region: Agency Region in which site is located;
NGR: British National Grid reference;
Station name: Name of station from Telemetry system;
Parameter: flow, rainfall, water level;
Qualifier: More detailed meta data relating to the value/ parameter above, i.e. logged, or type of gauge;
Units: Measurement units i.e. meters;
Value: The measurement itself.

(from Environment Agency)

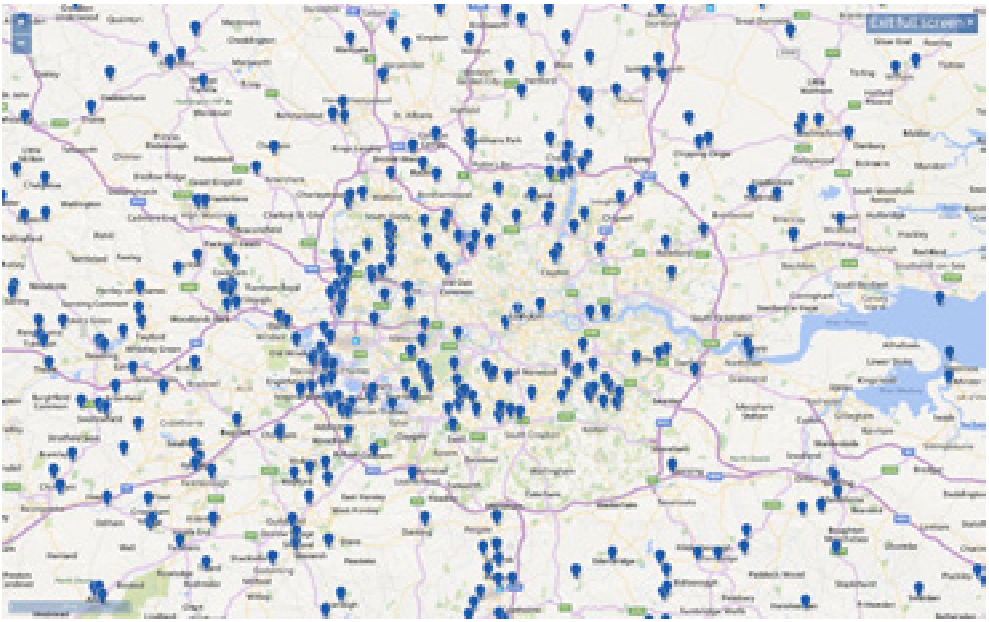


Fig. A_B2.1
Gauging station locations.

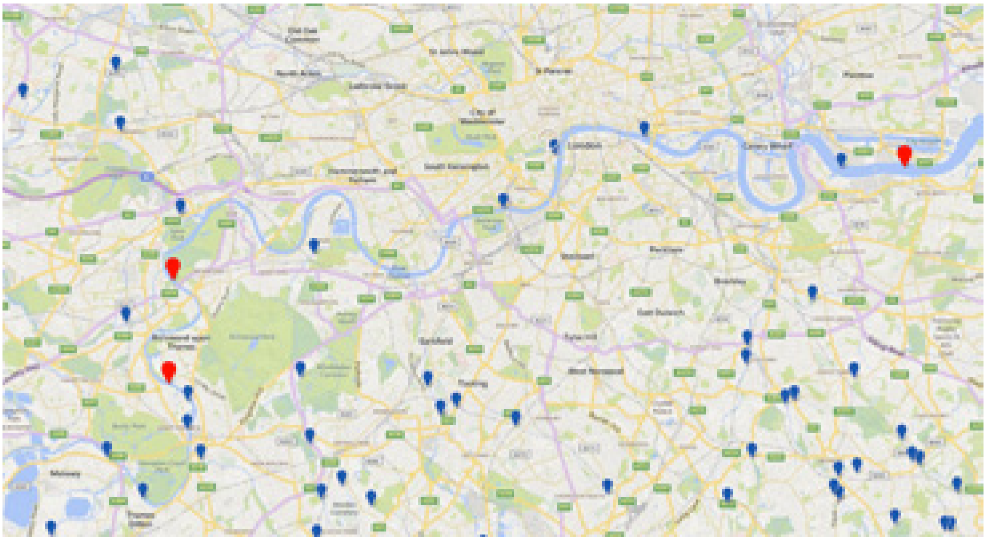


Fig. A_B2.2
The three gauging stations of the Thames tideway analyses, in red.

Time	stationReference	region	ngr	stationName	parameter	qualifier	units	value
2015-02-24T00:00:00Z	1	Thames	TQ4213079740	Silvertown	Water Level	Tidal Level	mAOD	-2.414
2015-02-24T00:00:00Z	6	Thames	TQ3032079700	Westminster	Water Level	Tidal Level	mAOD	-1.839
2015-02-24T00:00:00Z	19	Thames	TQ8906083020	Southend	Water Level	Tidal Level	mAOD	-0.845
2015-02-24T00:00:00Z	0130TH	Thames	SU00769733	RIVER THAMES AT EWEN	Water Level	Downstream	mASD	0.026
2015-02-24T00:00:00Z	0130TH	Thames	SU00769733	RIVER THAMES AT EWEN	Water Level	Stage	mASD	0.253
2015-02-24T00:00:00Z	0144TH	Thames	SU01969466	River Thames at Somerford Keynes	Water Level	Stage	mASD	0.885
2015-02-24T00:00:00Z	0155TH	Thames	ST99609260	Swill Brook at Oaksey	Water Level	Downstream	mASD	1.029
2015-02-24T00:00:00Z	0155TH	Thames	ST99609260	Swill Brook at Oaksey	Water Level	Stage	mASD	1.032
2015-02-24T00:00:00Z	0184TH	Thames	SU0881890496	RIVER KEY AT PURTON STOKE	Water Level	Stage	mASD	1.567
2015-02-24T00:00:00Z	0190TH	Thames	SU09409422	RIVER THAMES AT CRICKLADE	Water Level	Downstream	mASD	0.729
2015-02-24T00:00:00Z	0190TH	Thames	SU09409422	RIVER THAMES AT CRICKLADE	Water Level	Stage	mASD	0.733
2015-02-24T00:00:00Z	21009	North East	NT8983547675	Norham	Water Level	Stage	m	0.635
2015-02-24T00:00:00Z	21021	North East	NT7518435338	Sprouston	Water Level	Stage	m	0.848
2015-02-24T00:00:00Z	21030	North East	NT9976624867	Coldgate Mill	Water Level	Stage	m	0.126
2015-02-24T00:00:00Z	21033	North East	NT9942128073	Wooler	Water Level	Stage	m	0.125
2015-02-24T00:00:00Z	21037	North East	NU1464334354	Waren Mill	Water Level	Stage	m	0.094
2015-02-24T00:00:00Z	21038	North East	NT8997842377	Heaton Mill	Water Level	Stage	m	0.503
2015-02-24T00:00:00Z	21040	North East	NU1368428563	Warenford	Water Level	Stage	m	0.073
2015-02-24T00:00:00Z	21041	North East	NU1080233860	Belford	Water Level	Stage	m	0.131
2015-02-24T00:00:00Z	21999	North East	NT9977952641	Berwick	Water Level	Tidal Level	mAOD	-0.939
2015-02-24T00:00:00Z	22001	North East	NU2344304453	Morwick	Water Level	Stage	m	0.603
2015-02-24T00:00:00Z	22003	North East	NT8866507716	Shillmoor	Water Level	Stage	m	0.109
2015-02-24T00:00:00Z	22006	North East	NZ2433680000	Hartford Bridge	Water Level	Stage	m	0.255
2015-02-24T00:00:00Z	22007	North East	NZ1745885790	Mitford	Water Level	Stage	m	0.868
2015-02-24T00:00:00Z	22009	North East	NU0670601600	Rothbury	Water Level	Stage	m	0.645
2015-02-24T00:00:00Z	22010	North East	NZ0916771591	Stamfordham Heugh Mill	Water Level	Stage	m	0.139
2015-02-24T00:00:00Z	22011	North East	NZ0829586998	Hartburn	Water Level	Stage	m	0.152
2015-02-24T00:00:00Z	22012	North East	NZ0816871815	Stamfordham	Water Level	Stage	m	0.334
2015-02-24T00:00:00Z	22013	North East	NZ1662872766	Ponteland	Water Level	Stage	mAOD	55.107
2015-02-24T00:00:00Z	22014	North East	NT9227305641	Alwinton Bridge	Water Level	Stage	m	0.464
2015-02-24T00:00:00Z	22015	North East	NZ0534284128	Middleton Bridge	Water Level	Stage	m	0.245
2015-02-24T00:00:00Z	22016	North East	NZ0687093206	Nunnykirk	Water Level	Stage	m	0.505
2015-02-24T00:00:00Z	22017	North East	NZ1955985969	Morpeth	Water Level	Stage	mAOD	24.438
2015-02-24T00:00:00Z	22020	North East	NU2493806108	Warkworth	Water Level	Stage	m	0.342
2015-02-24T00:00:00Z	22999	North East	NZ3234380721	Blyth	Water Level	Tidal Level	mAOD	-1.535
2015-02-24T00:00:00Z	23001	North East	NZ0391361684	Bywell	Water Level	Stage	m	1.16
2015-02-24T00:00:00Z	23002	North East	NZ0416450803	Eddys Bridge	Water Level	Stage	m	0.299
2015-02-24T00:00:00Z	23003	North East	NY9055573231	Reaverhill	Water Level	Stage	m	1.177
2015-02-24T00:00:00Z	23004	North East	NY8562864666	Haydon Bridge	Water Level	Stage	m	0.629
2015-02-24T00:00:00Z	23006	North East	NY6721661064	Featherstone	Water Level	Stage	m	0.517
2015-02-24T00:00:00Z	23007	North East	NZ1679558096	Rowlands Gill	Water Level	Stage	m	0.197
2015-02-24T00:00:00Z	23008	North East	NY8683583225	Rede Bridge	Water Level	Stage	m	0.658
2015-02-24T00:00:00Z	23009	North East	NY7154846531	Alston	Water Level	Stage	m	0.472
2015-02-24T00:00:00Z	23011	North East	NY6444294681	Kielder	Water Level	Stage	m	0.427
2015-02-24T00:00:00Z	23016	North East	NZ2538067553	Jesmond Dene Craghall	Water Level	Stage	m	0.13
2015-02-24T00:00:00Z	23017	North East	NZ2496358467	Team Valley	Water Level	Stage	m	0.237
2015-02-24T00:00:00Z	23020	North East	NY9400564633	Hexham	Water Level	Stage	mAOD	31.542
2015-02-24T00:00:00Z	23021	North East	NY9859864468	Corbridge	Water Level	Stage	m	0.741
2015-02-24T00:00:00Z	23022	North East	NY7124587572	Ugly Dub	Water Level	Stage	m	0.647
2015-02-24T00:00:00Z	23023	North East	NZ0273261950	Riding Mill	Water Level	Stage	m	1.248
2015-02-24T00:00:00Z	23024	North East	NY8885292658	Otterburn Mill	Water Level	Stage	m	1.001
2015-02-24T00:00:00Z	23025	North East	NY9101466013	Warden Bridge End	Water Level	Stage	m	0.451
2015-02-24T00:00:00Z	23027	North East	NY7064263783	Haltwhistle	Water Level	Stage	m	0.814
2015-02-24T00:00:00Z	23028	North East	NY9196170577	Chollerford	Water Level	Stage	m	0.438
2015-02-24T00:00:00Z	23033	North East	NY8634194480	Otterburn	Water Level	Stage	m	1.08
2015-02-24T00:00:00Z	23036	North East	NY8307656672	Allen Mill Bridge	Water Level	Stage	m	0.362
2015-02-24T00:00:00Z	23037	North East	NY8334783197	Bellingham	Water Level	Stage	m	0.562
2015-02-24T00:00:00Z	23038	North East	NY9273363773	Hexham Maidenscroft	Water Level	Stage	m	0.159
2015-02-24T00:00:00Z	23039	North East	NY9333664362	Hexham Tanners Row BT	Water Level	Stage	m	0.888
2015-02-24T00:00:00Z	23041	North East	NY9333664362	Hexham Tanners Row BT	Water Level	Stage	m	-0.009
2015-02-24T00:00:00Z	23042	North East	NZ1933354758	Tanfield	Water Level	Stage	m	0.272
2015-02-24T00:00:00Z	23044	North East	NZ1213256823	Blackhall Mill	Water Level	Stage	m	0.163
2015-02-24T00:00:00Z	23053	North East	NY7238087040	Falstone	Water Level	Stage	m	0.497
2015-02-24T00:00:00Z	23054	North East	NZ2475069310	Gosforth	Water Level	Stage	m	0.285
2015-02-24T00:00:00Z	23055	North East	NY7072187144	Kielder Reservoir	Water Level	Reservoir Level	m	-1.913
2015-02-24T00:00:00Z	23058	North East	NY7905658286	Hindley Wrae	Water Level	Reservoir Level	m	0.405
2015-02-24T00:00:00Z	23060	North East	NZ0236651087	Derwent Reservoir	Water Level	Stage	m	-4.148
2015-02-24T00:00:00Z	23103	North East	NY6310093100	Butteryhaugh	Water Level	Stage	m	0.378
2015-02-24T00:00:00Z	24000	North East	NZ2193528311	South Church	Water Level	Stage	m	0.156
2015-02-24T00:00:00Z	24001	North East	NZ2653637721	Sunderland Bridge	Water Level	Stage	m	0.539
2015-02-24T00:00:00Z	24003	North East	NY9837439035	Stanhope	Water Level	Stage	m	0.484
2015-02-24T00:00:00Z	24004	North East	NZ1179932189	Bedburn	Water Level	Stage	m	0.389

Fig. A_B2.3
Excel standard file - Full daily file, edited by the Author.

Time	stationReference	region	ngr	stationName	parameter	qualifier	units	value
2015-02-24T00:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.610**
2015-02-24T00:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.605**
2015-02-24T00:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.604**
2015-02-24T00:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.603**
2015-02-24T01:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.598**
2015-02-24T01:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.597**
2015-02-24T01:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.594**
2015-02-24T01:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.591**
2015-02-24T02:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.591**
2015-02-24T02:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.590**
2015-02-24T02:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.584**
2015-02-24T02:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.591**
2015-02-24T03:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.584**
2015-02-24T03:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.581**
2015-02-24T03:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.579**
2015-02-24T03:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.577**
2015-02-24T04:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.579**
2015-02-24T04:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.576**
2015-02-24T04:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.575**
2015-02-24T04:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.575**
2015-02-24T05:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.577**
2015-02-24T05:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.577**
2015-02-24T05:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.576**
2015-02-24T05:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.590**
2015-02-24T06:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.638**
2015-02-24T06:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.697**
2015-02-24T06:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.740**
2015-02-24T06:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.746**
2015-02-24T07:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.720**
2015-02-24T07:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.684**
2015-02-24T07:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.660**
2015-02-24T07:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.638**
2015-02-24T08:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.621**
2015-02-24T08:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.608**
2015-02-24T08:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.600**
2015-02-24T08:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.592**
2015-02-24T09:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.592**
2015-02-24T09:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.586**
2015-02-24T09:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.580**
2015-02-24T09:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.579**
2015-02-24T10:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.577**
2015-02-24T10:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.580**
2015-02-24T10:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.584**
2015-02-24T10:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.598**
2015-02-24T11:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.601**
2015-02-24T11:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.607**
2015-02-24T11:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.613**
2015-02-24T11:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.615**
2015-02-24T12:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.619**
2015-02-24T12:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.618**
2015-02-24T12:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.623**
2015-02-24T12:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.637**
2015-02-24T13:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.646**
2015-02-24T13:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.645**
2015-02-24T13:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.643**
2015-02-24T13:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.642**
2015-02-24T14:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.643**
2015-02-24T14:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.642**
2015-02-24T14:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.651**
2015-02-24T14:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.655**
2015-02-24T15:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.661**
2015-02-24T15:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.605**
2015-02-24T15:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.577**
2015-02-24T15:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.565**
2015-02-24T16:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.544**
2015-02-24T16:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.536**
2015-02-24T16:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Water Level	Stage	mAOD	**4.520**

Fig. A_B*2.4*

Excel standard file - E.g. Thames at Kingston (Teddington), water level, edited by the Author.

Time	stationReference	region	ngr	stationName	parameter	units	value
2015-02-24T00:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**159.709**
2015-02-24T00:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**158.900**
2015-02-24T00:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**158.860**
2015-02-24T00:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**158.036**
2015-02-24T01:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**157.860**
2015-02-24T01:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**156.807**
2015-02-24T01:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**156.490**
2015-02-24T01:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**155.938**
2015-02-24T02:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**155.248**
2015-02-24T02:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**155.170**
2015-02-24T02:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**154.442**
2015-02-24T02:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**153.971**
2015-02-24T03:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**154.551**
2015-02-24T03:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**154.218**
2015-02-24T03:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**153.672**
2015-02-24T03:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**153.513**
2015-02-24T04:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**153.654**
2015-02-24T04:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**152.911**
2015-02-24T04:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**152.909**
2015-02-24T04:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**152.731**
2015-02-24T05:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**152.506**
2015-02-24T05:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**152.886**
2015-02-24T05:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**151.684**
2015-02-24T05:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**147.323**
2015-02-24T06:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**136.420**
2015-02-24T06:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**129.705**
2015-02-24T06:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**132.283**
2015-02-24T06:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**144.290**
2015-02-24T07:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**159.095**
2015-02-24T07:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**165.125**
2015-02-24T07:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**164.800**
2015-02-24T07:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**162.423**
2015-02-24T08:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**160.083**
2015-02-24T08:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**158.490**
2015-02-24T08:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**157.013**
2015-02-24T08:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**155.392**
2015-02-24T09:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**155.227**
2015-02-24T09:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**154.190**
2015-02-24T09:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**153.309**
2015-02-24T09:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**152.752**
2015-02-24T10:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**152.339**
2015-02-24T10:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**153.145**
2015-02-24T10:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**156.591**
2015-02-24T10:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**157.829**
2015-02-24T11:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**159.382**
2015-02-24T11:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**160.756**
2015-02-24T11:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**161.374**
2015-02-24T11:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**161.833**
2015-02-24T12:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**162.118**
2015-02-24T12:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**163.012**
2015-02-24T12:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**164.684**
2015-02-24T12:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**166.756**
2015-02-24T13:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**168.706**
2015-02-24T13:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**167.929**
2015-02-24T13:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**168.056**
2015-02-24T13:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**168.306**
2015-02-24T14:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**168.012**
2015-02-24T14:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**167.409**
2015-02-24T14:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**169.349**
2015-02-24T14:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**172.203**
2015-02-24T15:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**175.568**
2015-02-24T15:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**188.707**
2015-02-24T15:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**185.629**
2015-02-24T15:45:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**182.589**
2015-02-24T16:00:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**180.372**
2015-02-24T16:15:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**178.689**
2015-02-24T16:30:00Z	3400TH	Thames	TQ17706980	THAMES AT KINGSTON (TEDDINGTON)	Flow	m3/s	**177.052**

Fig. A_B2.5
Excel standard file - E.g. Thames at Kingston (Teddington), flow, edited by the Author.

DATE		KINGSTON (Teddington)				RICHMOND		SILVERTOWN		LNDststd
OCTOBER	**level**	**flow**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**rain**
2014-10-07	max	**55.807**	-	**4.575**	-	**4.145**	-	**3.531**	-	3.0
fm	max	**46.342**	83%	**4.563**	100%	**4.537**	109%	**3.890**	110%	1.0
2014-10-09	max	**77.479**	167%	**4.725**	104%	**4.698**	104%	**4.231**	109%	3.0
2014-10-10	max	**92.841**	120%	**4.839**	102%	**4.808**	102%	**4.257**	101%	3.0
2014-10-11	max	**56.927**	61%	**4.631**	96%	**4.661**	97%	**4.099**	96%	0.5
2014-10-12	max	**51.924**	91%	**4.641**	100%	**4.624**	99%	**4.004**	98%	10.0
2014-10-13	max	**100.576**	194%	**4.688**	101%	**4.591**	99%	**3.876**	97%	17.0
2014-10-14	max	**105.786**	105%	**4.566**	97%	**4.207**	92%	**3.454**	89%	0.5
2014-10-15	max	**98.802**	93%	**4.589**	101%	**3.819**	91%	**3.165**	92%	9.0
2014-10-16	max	**84.758**	86%	**4.594**	100%	**3.591**	94%	**2.890**	91%	1.0
2014-10-17	max	**100.168**	118%	**4.607**	100%	**3.412**	95%	**2.729**	94%	1.0
2014-10-18	max	**86.995**	87%	**4.547**	99%	**3.364**	99%	**2.758**	101%	0.0
2014-10-19	max	**65.464**	75%	**4.487**	99%	**3.262**	97%	**2.923**	106%	2.0
2014-10-20	max	**50.684**	77%	**4.483**	100%	**3.613**	111%	**3.132**	107%	0.5
2014-10-21	max	**31.306**	62%	**4.509**	101%	**3.731**	103%	**3.861**	123%	3.0
2014-10-22	max	**66.424**	212%	**4.732**	105%	**4.720**	127%	**4.187**	108%	0.0
2014-10-23	max	**17.826**	27%	**4.488**	95%	**4.119**	87%	**3.575**	85%	0.0
nm	max	**30.014**	168%	**4.540**	101%	**4.485**	109%	**3.890**	109%	2.0
2014-10-25	max	**28.828**	96%	**4.535**	100%	**4.493**	100%	**3.960**	102%	0.0
2014-10-26	max	**19.350**	67%	**4.496**	99%	**4.280**	95%	**3.769**	95%	0.0
2014-10-27	max	**20.751**	107%	**4.506**	100%	**4.412**	103%	**3.821**	101%	0.0
2014-10-28	max	**18.607**	90%	**4.491**	100%	**4.229**	96%	**3.692**	97%	0.0
2014-10-29	max	**68.528**	368%	**4.519**	101%	**4.339**	103%	**3.744**	101%	3.0
2014-10-30	max	**19.873**	29%	**4.509**	100%	**3.833**	88%	**3.242**	87%	0.0
2014-10-31	max	**20.703**	104%	**4.503**	100%	**3.668**	96%	**3.132**	97%	0.5
2014-10-07	min	**18.376**	-	**4.420**	-	-0.306	-	**-2.996**	-	3.0
fm	min	**2.780**	15%	**4.410**	100%	-0.452	148%	**-3.033**	101%	1.0
2014-10-09	min	**9.327**	336%	**4.444**	101%	-0.401	89%	**-3.154**	104%	3.0
2014-10-10	min	**3.914**	42%	**4.431**	100%	-0.354	88%	**-2.879**	91%	3.0
2014-10-11	min	**11.858**	303%	**4.401**	99%	-0.636	180%	**-2.791**	97%	0.5
2014-10-12	min	**6.447**	54%	**4.412**	100%	-0.808	127%	**-2.564**	92%	10.0
2014-10-13	min	**19.204**	298%	**4.501**	102%	-0.167	21%	**-2.242**	87%	17.0
2014-10-14	min	**75.896**	395%	**4.464**	99%	0.544	-326%	**-2.157**	96%	0.5
2014-10-15	min	**28.278**	37%	**4.362**	98%	0.119	22%	**-1.850**	86%	9.0
2014-10-16	min	**54.572**	193%	**4.512**	103%	0.119	100%	**-1.634**	88%	1.0
2014-10-17	min	**67.667**	124%	**4.523**	100%	0.324	272%	**-1.417**	87%	1.0
2014-10-18	min	**52.747**	78%	**4.393**	97%	-0.086	-27%	**-1.751**	124%	0.0
2014-10-19	min	**43.213**	82%	**4.434**	101%	-0.064	74%	**-1.850**	106%	2.0
2014-10-20	min	**27.044**	63%	**4.411**	99%	-0.302	472%	**-2.018**	109%	0.5
2014-10-21	min	**8.033**	30%	**4.399**	100%	**-0.628**	208%	**-2.121**	105%	3.0
2014-10-22	min	**13.693**	170%	**4.452**	101%	**-0.658**	105%	**-2.546**	120%	0.0
2014-10-23	min	**6.923**	51%	**4.431**	100%	**-0.815**	124%	**-2.656**	104%	0.0
nm	min	**8.134**	117%	**4.452**	100%	**-0.735**	90%	**-2.487**	94%	2.0
2014-10-25	min	**1.433**	18%	**4.477**	101%	**-0.808**	110%	**-2.732**	110%	0.0
2014-10-26	min	**12.249**	855%	**4.471**	100%	**-0.786**	97%	**-2.549**	93%	0.0
2014-10-27	min	**8.518**	70%	**4.467**	100%	**-0.709**	90%	**-2.549**	100%	0.0
2014-10-28	min	**12.493**	147%	**4.471**	100%	**-0.844**	119%	**-2.505**	98%	0.0
2014-10-29	min	**9.860**	79%	**4.474**	100%	**-0.877**	104%	**-2.091**	83%	3.0
2014-10-30	min	**11.419**	116%	**4.472**	100%	**-0.757**	86%	**-2.289**	109%	0.0
2014-10-31	min	**14.226**	125%	**4.488**	100%	**-0.738**	97%	**-2.062**	90%	0.5

Fig. A_B2.6
water dynamics table - October 2013

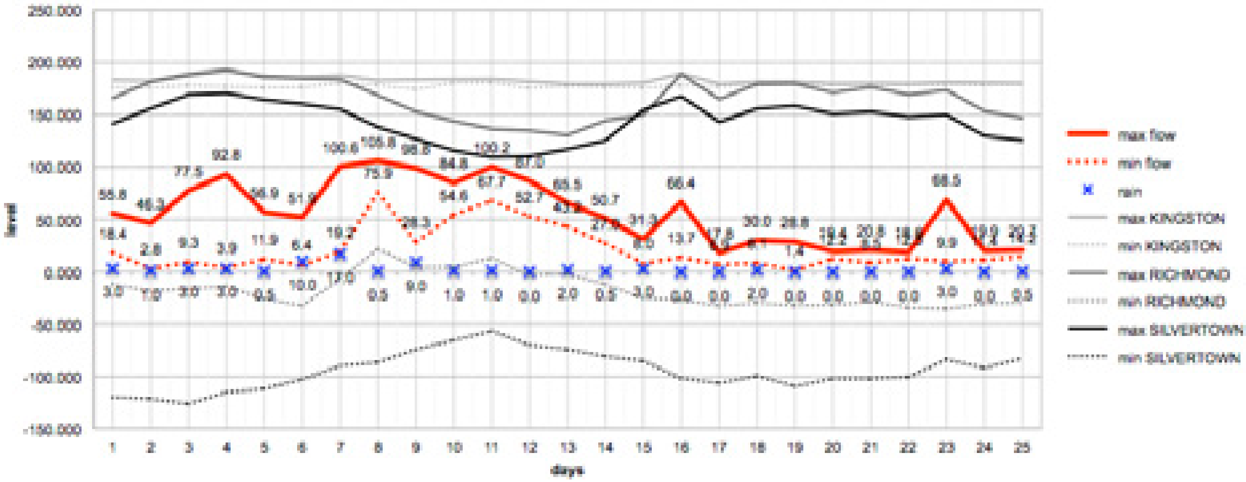


Fig. A_B2.7
water dynamics chart - October 2013

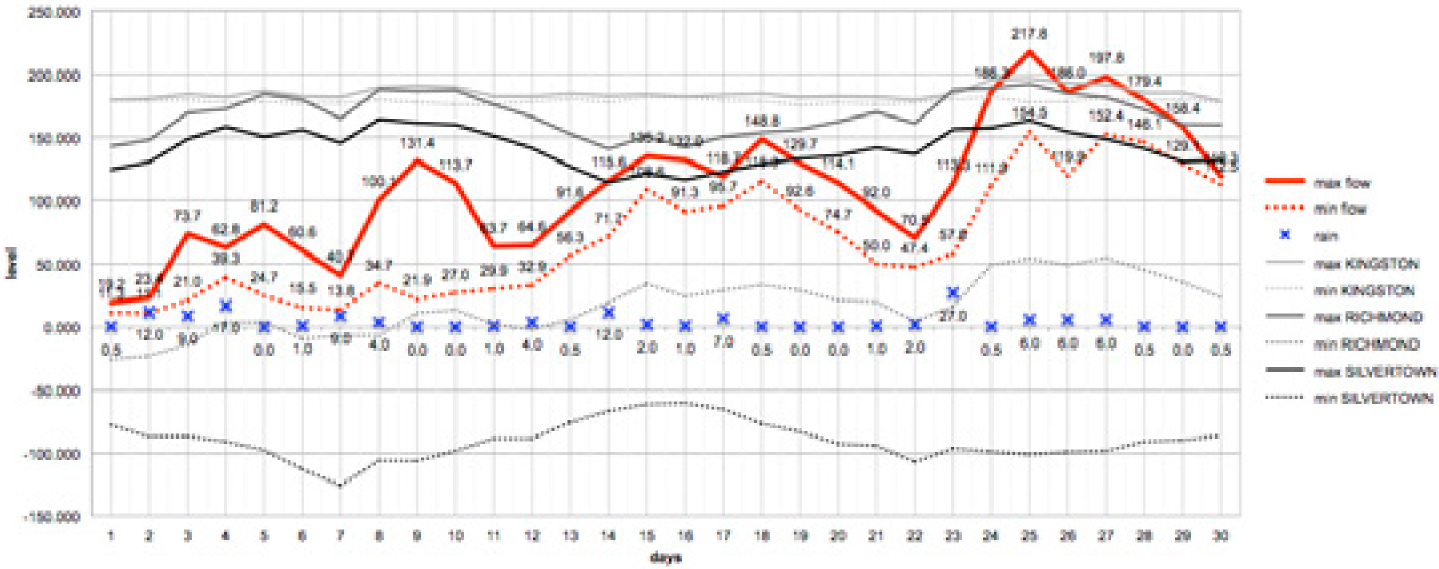
		KINGSTON (Teddington)				RICHMOND		SILVERTOWN		LNDststd
NOVEMBER	**level**	**flow**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**rain**
2014-11-01	max	**19.163**	93%	**4.495**	100%	**3.580**	98%	**3.114**	99%	0.5
2014-11-02	max	**23.366**	122%	**4.520**	101%	**3.701**	103%	**3.264**	105%	12.0
2014-11-03	max	**73.663**	315%	**4.601**	102%	**4.240**	115%	**3.722**	114%	9.0
2014-11-04	max	**62.789**	85%	**4.548**	99%	**4.309**	102%	**3.960**	106%	17.0
2014-11-05	max	**81.188**	129%	**4.676**	103%	**4.610**	107%	**3.769**	95%	0.0
fm	max	**60.556**	75%	**4.561**	98%	**4.493**	97%	**3.901**	104%	1.0
2014-11-07	max	**40.708**	67%	**4.546**	100%	**4.123**	92%	**3.641**	93%	9.0
2014-11-08	max	**100.103**	246%	**4.736**	104%	**4.694**	114%	**4.110**	113%	4.0
2014-11-09	max	**131.433**	131%	**4.772**	101%	**4.668**	99%	**4.037**	98%	0.0
2014-11-10	max	**113.729**	87%	**4.745**	99%	**4.679**	100%	**4.004**	99%	0.0
2014-11-11	max	**63.679**	56%	**4.560**	96%	**4.401**	94%	**3.777**	94%	1.0
2014-11-12	max	**64.550**	101%	**4.561**	100%	**4.156**	94%	**3.539**	94%	4.0
2014-11-13	max	**91.629**	142%	**4.613**	101%	**3.819**	92%	**3.176**	90%	0.5
2014-11-14	max	**115.589**	126%	**4.576**	99%	**3.526**	92%	**2.854**	90%	12.0
2014-11-15	max	**135.239**	117%	**4.603**	101%	**3.775**	107%	**3.040**	107%	2.0
2014-11-16	max	**131.978**	98%	**4.554**	99%	**3.562**	94%	**2.912**	96%	1.0
2014-11-17	max	**118.734**	90%	**4.587**	101%	**3.767**	106%	**3.073**	106%	7.0
2014-11-18	max	**148.806**	125%	**4.613**	101%	**3.848**	102%	**3.224**	105%	0.5
2014-11-19	max	**129.740**	87%	**4.538**	98%	**3.906**	102%	**3.333**	103%	0.0
2014-11-20	max	**114.106**	88%	**4.562**	101%	**4.060**	104%	**3.399**	102%	0.0
2014-11-21	max	**91.970**	81%	**4.550**	100%	**4.251**	105%	**3.553**	105%	1.0
nm	max	**70.452**	77%	**4.503**	99%	**4.027**	95%	**3.421**	96%	2.0
2014-11-23	max	**113.288**	161%	**4.603**	102%	**4.687**	116%	**3.909**	114%	27.0
2014-11-24	max	**186.254**	164%	**4.890**	106%	**4.720**	101%	**3.938**	101%	0.5
2014-11-25	max	**217.765**	117%	**4.908**	100%	**4.804**	102%	**4.092**	104%	6.0
2014-11-26	max	**186.044**	85%	**4.826**	98%	**4.621**	96%	**3.861**	94%	6.0
2014-11-27	max	**197.769**	106%	**4.791**	99%	**4.537**	98%	**3.722**	96%	6.0
2014-11-28	max	**179.429**	91%	**4.634**	97%	**4.295**	95%	**3.528**	95%	0.5
2014-11-29	max	**158.352**	88%	**4.631**	100%	**4.005**	93%	**3.271**	93%	0.0
2014-11-30	max	**119.335**	75%	**4.464**	96%	**4.002**	100%	**3.308**	101%	0.5
2014-11-01	min	**11.276**	79%	**4.476**	100%	**-0.640**	87%	**-1.941**	94%	0.5
2014-11-02	min	**11.108**	99%	**4.475**	100%	**-0.570**	89%	**-2.168**	112%	12.0
2014-11-03	min	**21.026**	189%	**4.499**	101%	**-0.340**	60%	**-2.165**	100%	9.0
2014-11-04	min	**39.268**	187%	**4.426**	98%	**0.100**	-29%	**-2.264**	105%	17.0
2014-11-05	min	**24.697**	63%	**4.457**	101%	**0.090**	90%	**-2.436**	108%	0.0
fm	min	**15.532**	63%	**4.417**	99%	**-0.240**	-267%	**-2.820**	116%	1.0
2014-11-07	min	**13.811**	89%	**4.433**	100%	**-0.170**	71%	**-3.143**	111%	9.0
2014-11-08	min	**34.681**	251%	**4.492**	101%	**-0.170**	100%	**-2.645**	84%	4.0
2014-11-09	min	**21.908**	63%	**4.443**	99%	**0.270**	-159%	**-2.648**	100%	0.0
2014-11-10	min	**26.966**	123%	**4.408**	99%	**0.340**	126%	**-2.450**	93%	0.0
2014-11-11	min	**29.898**	111%	**4.408**	100%	**0.050**	15%	**-2.205**	90%	1.0
2014-11-12	min	**32.858**	110%	**4.462**	101%	**-0.050**	-100%	**-2.205**	100%	4.0
2014-11-13	min	**56.346**	171%	**4.514**	101%	**0.150**	-300%	**-1.886**	86%	0.5
2014-11-14	min	**71.650**	127%	**4.450**	99%	**0.490**	327%	**-1.663**	88%	12.0
2014-11-15	min	**108.580**	152%	**4.548**	102%	**0.850**	173%	**-1.524**	92%	2.0
2014-11-16	min	**91.332**	84%	**4.552**	100%	**0.610**	72%	**-1.502**	99%	1.0
2014-11-17	min	**95.678**	105%	**4.485**	99%	**0.720**	118%	**-1.626**	108%	7.0
2014-11-18	min	**115.253**	120%	**4.474**	100%	**0.830**	115%	**-1.919**	118%	0.5
2014-11-19	min	**92.646**	80%	**4.394**	98%	**0.720**	87%	**-2.077**	108%	0.0
2014-11-20	min	**74.715**	81%	**4.436**	101%	**0.530**	74%	**-2.308**	111%	0.0
2014-11-21	min	**49.978**	67%	**4.411**	99%	**0.490**	92%	**-2.348**	102%	1.0
nm	min	**47.403**	95%	**4.440**	101%	**0.110**	22%	**-2.667**	114%	2.0
2014-11-23	min	**57.829**	122%	**4.506**	101%	**0.410**	373%	**-2.399**	90%	27.0
2014-11-24	min	**111.855**	193%	**4.545**	101%	**1.225**	299%	**-2.461**	103%	0.5
2014-11-25	min	**154.489**	138%	**4.446**	98%	**1.350**	110%	**-2.520**	102%	6.0
2014-11-26	min	**119.925**	78%	**4.460**	100%	**1.225**	91%	**-2.465**	98%	6.0
2014-11-27	min	**152.423**	127%	**4.537**	102%	**1.364**	111%	**-2.447**	99%	6.0
2014-11-28	min	**146.101**	96%	**4.468**	98%	**1.126**	83%	**-2.267**	93%	0.5
2014-11-29	min	**129.066**	88%	**4.514**	101%	**0.888**	79%	**-2.242**	99%	0.0
2014-11-30	min	**112.541**	87%	**4.431**	98%	**0.591**	67%	**-2.154**	96%	0.5

Fig. A_B2.8
water dynamics table - November 2013

			KINGSTON (Teddington)			RICHMOND		SILVERTOWN		LNDststd
DECEMBER	level	flow	↑↓	water level	↑↓	water level	↑↓	water level	↑↓	rain
2014-12-01	max	94.902	80%	4.589	103%	3.903	98%	3.209	97%	0.0
2014-12-02	max	92.964	98%	4.580	100%	4.053	104%	4.053	126%	1.0
2014-12-03	max	74.854	79%	4.511	98%	3.756	96%	3.594	112%	0.5
2014-12-04	max	72.760	78%	4.497	98%	4.243	105%	3.344	83%	4.0
2014-12-05	max	70.544	94%	4.524	100%	4.258	113%	3.583	100%	0.0
fm	max	63.583	87%	4.546	101%	4.386	103%	3.744	104%	0.5
2014-12-07	max	54.958	78%	4.528	100%	4.115	97%	3.509	94%	1.0
2014-12-08	max	61.480	97%	4.556	100%	4.298	98%	3.674	105%	0.0
2014-12-09	max	57.016	104%	4.567	101%	4.482	109%	3.843	105%	1.0
2014-12-10	max	48.593	79%	4.529	99%	4.159	97%	3.568	93%	1.0
2014-12-11	max	51.293	90%	4.542	99%	4.137	92%	3.557	100%	0.5
2014-12-12	max	79.560	164%	4.544	100%	4.207	101%	3.535	99%	10.0
2014-12-13	max	126.196	246%	4.593	101%	3.947	95%	3.315	94%	0.0
2014-12-14	max	109.991	138%	4.511	99%	3.251	77%	2.681	81%	1.0
2014-12-15	max	78.523	71%	4.504	100%	3.668	113%	3.044	114%	0.5
2014-12-16	max	76.428	97%	4.498	100%	3.284	90%	2.799	92%	3.0
2014-12-17	max	114.595	150%	4.586	102%	3.815	116%	3.147	112%	5.0
2014-12-18	max	135.399	118%	4.554	99%	3.588	94%	2.982	95%	0.0
2014-12-19	max	130.628	96%	4.558	100%	4.225	118%	3.509	118%	1.0
2014-12-20	max	108.301	83%	4.486	98%	3.917	93%	3.462	99%	0.0
2014-12-21	max	99.386	92%	4.488	100%	4.159	106%	3.583	103%	0.0
nm	max	84.983	86%	4.548	101%	4.379	105%	3.718	104%	0.0
2014-12-23	max	71.099	84%	4.507	99%	4.364	100%	3.736	100%	0.0
2014-12-24	max	71.294	100%	4.488	100%	3.998	92%	3.696	99%	0.5
2014-12-25	max	n	-	n	-	n	-	n	-	0.0
2014-12-26	max	n	-	n	-	n	-	n	-	8.0
2014-12-27	max	n	-	n	-	n	-	n	-	1.0
2014-12-28	max	n	-	n	-	n	-	n	-	0.0
2014-12-29	max	n	-	n	-	n	-	n	-	0.5
2014-12-30	max	n	-	n	-	n	-	n	-	0.5
2014-12-31	max	n	-	n	-	n	-	n	-	0.5
2014-12-01	min	64.972	58%	4.377	99%	0.430	73%	-2.088	97%	0.0
2014-12-02	min	67.288	104%	4.476	102%	0.222	52%	0.222	-11%	1.0
2014-12-03	min	60.343	93%	4.444	102%	0.251	58%	-2.267	-1021%	0.5
2014-12-04	min	58.636	87%	4.455	100%	0.222	100%	-2.436	107%	4.0
2014-12-05	min	39.288	65%	4.377	98%	0.134	53%	-2.436	100%	0.0
fm	min	46.853	80%	4.461	100%	0.009	4%	-2.710	111%	0.5
2014-12-07	min	48.536	124%	4.490	103%	-0.108	-81%	-2.787	103%	1.0
2014-12-08	min	41.846	89%	4.449	100%	0.005	56%	-2.469	89%	0.0
2014-12-09	min	23.888	49%	4.400	98%	-0.130	120%	-3.143	127%	1.0
2014-12-10	min	28.169	67%	4.446	100%	-0.189	-3780%	-2.275	72%	1.0
2014-12-11	min	36.308	152%	4.468	102%	-0.189	145%	-2.425	107%	0.5
2014-12-12	min	42.288	150%	4.448	100%	-0.105	56%	-2.157	89%	10.0
2014-12-13	min	80.137	221%	4.469	100%	0.482	-255%	-2.018	94%	0.0
2014-12-14	min	61.171	145%	4.386	99%	0.357	-340%	-2.227	110%	1.0
2014-12-15	min	67.387	84%	4.498	103%	0.269	75%	-1.809	81%	0.5
2014-12-16	min	45.816	75%	4.430	98%	0.009	3%	-1.685	93%	3.0
2014-12-17	min	60.091	89%	4.429	100%	0.243	2700%	-1.828	108%	5.0
2014-12-18	min	90.356	197%	4.433	100%	0.661	272%	-2.106	115%	0.0
2014-12-19	min	107.037	178%	4.402	99%	0.819	124%	-1.938	92%	1.0
2014-12-20	min	92.450	102%	4.385	100%	0.657	80%	-2.139	110%	0.0
2014-12-21	min	66.483	62%	4.402	100%	0.401	61%	-2.960	138%	0.0
nm	min	79.831	86%	4.519	103%	0.243	61%	-2.615	88%	0.0
2014-12-23	min	50.302	76%	4.441	98%	0.130	53%	-2.703	103%	0.0
2014-12-24	min	69.692	87%	4.467	101%	0.280	215%	i	-	0.5
2014-12-25	min	n	-	n	-	n	-	n	-	0.0
2014-12-26	min	n	-	n	-	n	-	n	-	8.0
2014-12-27	min	n	-	n	-	n	-	n	-	1.0
2014-12-28	min	n	-	n	-	n	-	n	-	0.0
2014-12-29	min	n	-	n	-	n	-	n	-	0.5
2014-12-30	min	n	-	n	-	n	-	n	-	0.5
2014-12-31	min	n	-	n	-	n	-	n	-	0.5

Fig. A_B2.9
water dynamics table - December 2013

Fig. A_B2.10
water dynamics chart - November 2013



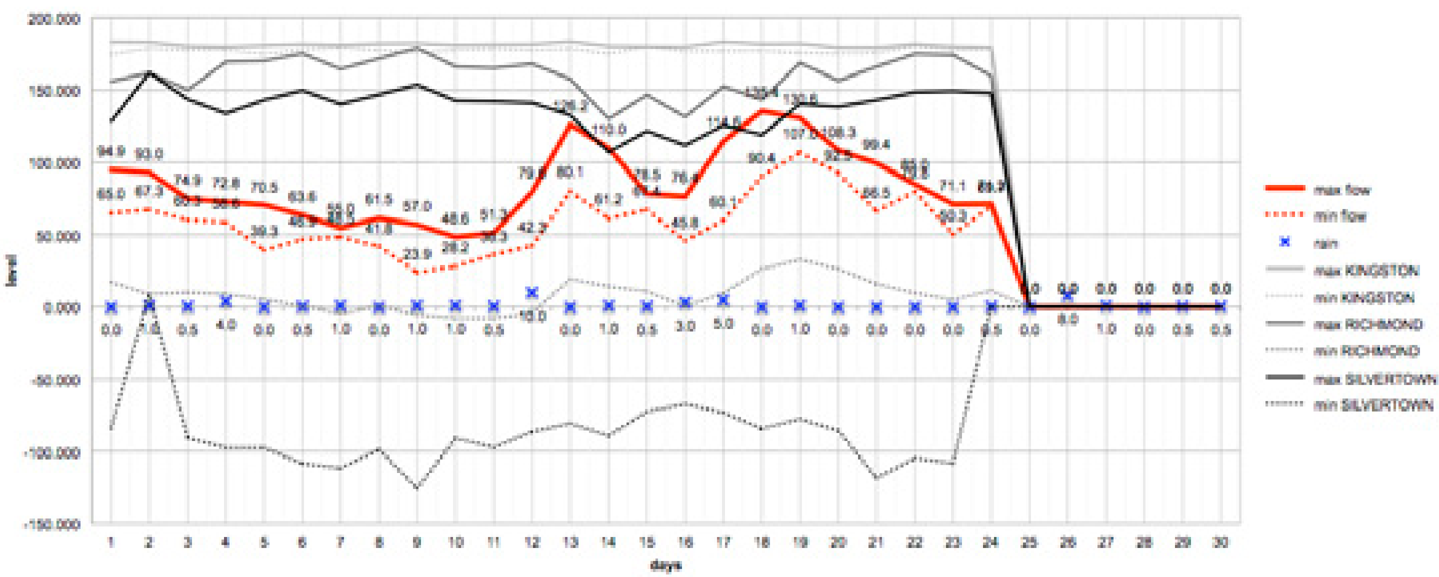


Fig. A_B2.11
water dynamics chart - December 2013

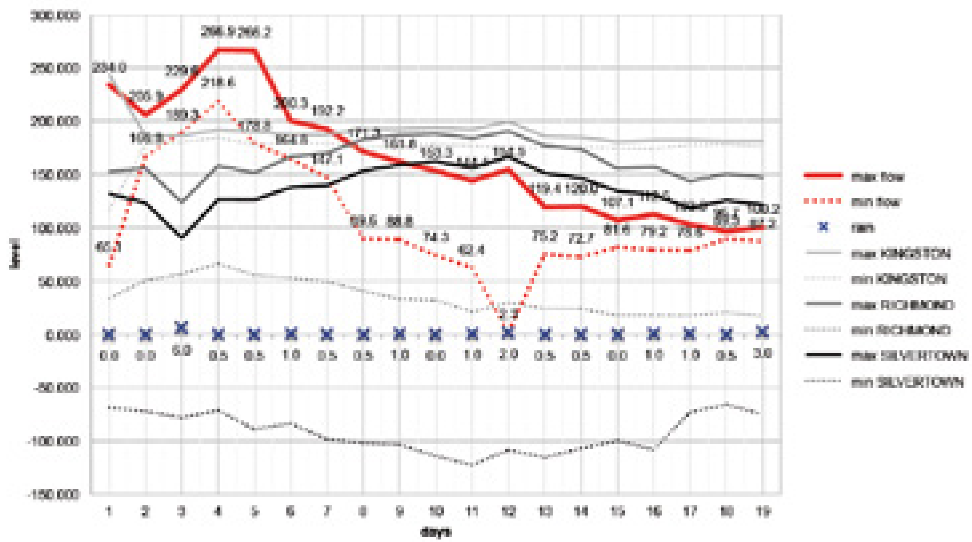
			KINGSTON (Teddington)			RICHMOND		SILVERTOWN		LNDststd
JANUARY	**level**	**flow**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**water level**	**↑↓**	**rain**
2014-01-13	max	**234.003**	-	**6.099**	-	**3.815**	-	**3.297**	-	0.0
2014-01-14	max	**205.858**	88%	**4.645**	76%	**3.899**	102%	**3.081**	93%	0.0
2014-01-15	max	**229.565**	112%	**4.660**	100%	**3.093**	79%	**2.260**	73%	6.0
2014-01-16	max	**266.933**	116%	**4.795**	103%	**3.954**	128%	**3.158**	140%	0.5
2014-01-17	max	**266.228**	100%	**4.750**	99%	**3.786**	96%	**3.154**	100%	0.5
2014-01-18	max	**200.258**	75%	**4.684**	99%	**4.163**	110%	**3.447**	109%	1.0
2014-01-19	max	**192.248**	96%	**4.688**	100%	**4.251**	102%	**3.495**	101%	0.5
2014-01-20	max	**171.267**	89%	**4.803**	102%	**4.577**	108%	**3.835**	110%	0.5
nm	max	**161.784**	94%	**4.814**	100%	**4.676**	102%	**3.978**	104%	1.0
2014-01-22	max	**153.309**	95%	**4.839**	101%	**4.705**	101%	**4.055**	102%	0.0
2014-01-23	max	**144.130**	94%	**4.803**	99%	**4.602**	98%	**3.905**	96%	1.0
2014-01-24	max	**154.515**	107%	**4.985**	104%	**4.760**	103%	**4.161**	107%	2.0
2014-01-25	max	**119.366**	77%	**4.640**	93%	**4.419**	93%	**3.780**	91%	0.5
2014-01-26	max	**119.998**	101%	**4.625**	100%	**4.342**	98%	**3.663**	97%	0.5
2014-01-27	max	**107.087**	89%	**4.515**	98%	**3.885**	89%	**3.359**	92%	0.0
2014-01-28	max	**112.455**	105%	**4.550**	101%	**3.936**	101%	**3.271**	97%	1.0
2014-01-29	max	**103.014**	92%	**4.559**	100%	**3.591**	91%	**2.960**	90%	1.0
2014-01-30	max	**96.684**	94%	**4.530**	99%	**3.767**	105%	**3.136**	106%	0.5
2014-01-31	max	**100.201**	104%	**4.529**	100%	**3.683**	98%	**3.044**	97%	3.0
2014-01-13	min	**65.052**	-	**2.919**	-	**0.844**	-	**-1.714**	-	0.0
2014-01-14	min	**166.849**	256%	**4.460**	153%	**1.273**	151%	**-1.802**	105%	0.0
2014-01-15	min	**189.300**	113%	**4.506**	101%	**1.412**	111%	**-1.949**	108%	6.0
2014-01-16	min	**218.605**	115%	**4.616**	102%	**1.654**	117%	**-1.780**	91%	0.5
2014-01-17	min	**178.849**	82%	**4.445**	96%	**1.390**	84%	**-2.223**	125%	0.5
2014-01-18	min	**164.792**	92%	**4.499**	101%	**1.328**	96%	**-2.088**	94%	1.0
2014-01-19	min	**147.050**	89%	**4.468**	99%	**1.236**	93%	**-2.458**	118%	0.5
2014-01-20	min	**89.593**	61%	**4.374**	98%	**1.020**	83%	**-2.546**	104%	0.5
nm	min	**88.753**	99%	**4.407**	101%	**0.830**	81%	**-2.586**	102%	1.0
2014-01-22	min	**74.258**	84%	**4.445**	101%	**0.800**	96%	**-2.850**	110%	0.0
2014-01-23	min	**62.439**	84%	**4.422**	99%	**0.533**	67%	**-3.062**	107%	1.0
2014-01-24	min	**2.266**	4%	**4.359**	99%	**0.734**	138%	**-2.710**	89%	2.0
2014-01-25	min	**75.167**	3317%	**4.379**	100%	**0.606**	83%	**-2.886**	106%	0.5
2014-01-26	min	**72.748**	97%	**4.390**	100%	**0.606**	100%	**-2.670**	93%	0.5
2014-01-27	min	**81.625**	112%	**4.365**	99%	**0.445**	73%	**-2.494**	93%	0.0
2014-01-28	min	**79.181**	97%	**4.351**	100%	**0.445**	100%	**-2.699**	108%	1.0
2014-01-29	min	**78.550**	99%	**4.441**	102%	**0.438**	98%	**-1.824**	68%	1.0
2014-01-30	min	**89.323**	114%	**4.448**	100%	**0.518**	118%	**-1.641**	90%	0.5
2014-01-31	min	**87.208**	98%	**4.396**	99%	**0.427**	82%	**-1.875**	114%	3.0

Fig. A_B2.12
water dynamics table - January 2014

			KINGSTON (Teddington)			RICHMOND		SILVERTOWN		LNDststd
FEBRUARY	level	flow	↑↓	water level	↑↓	water level	↑↓	water level	↑↓	rain
2014-02-01	max	88.453	88%	4.480	99%	3.591	98%	2.927	96%	0.5
2014-02-02	max	88.158	100%	4.566	102%	4.013	112%	3.374	115%	0.0
fm	max	89.688	102%	4.575	100%	4.280	107%	3.583	106%	0.0
2014-02-04	max	89.860	100%	4.537	99%	4.152	97%	3.469	97%	0.0
2014-02-05	max	78.056	87%	4.540	100%	4.254	102%	3.575	103%	0.5
2014-02-06	max	77.651	99%	4.531	100%	4.225	99%	3.524	99%	0.0
2014-02-07	max	73.791	95%	4.498	99%	4.002	95%	3.330	94%	0.5
2014-02-08	max	71.190	96%	4.493	100%	4.024	101%	3.396	102%	0.0
2014-02-09	max	69.781	98%	4.471	100%	3.972	99%	3.337	98%	0.0
2014-02-10	max	68.559	98%	4.460	100%	3.764	95%	3.132	94%	0.0
2014-02-11	max	64.082	93%	4.460	100%	3.522	94%	2.887	92%	0.0
2014-02-12	max	66.506	104%	4.488	101%	3.386	96%	2.857	99%	0.0
2014-02-13	max	73.720	111%	4.515	101%	3.115	92%	2.520	88%	7.0
2014-02-14	max	n	-	n	-	n	-	n	-	0.5
2014-02-15	max	n	-	n	-	n	-	n	-	0.0
2014-02-16	max	n	-	n	-	n	-	n	-	6.0
2014-02-17	max	n	-	n	-	n	-	n	-	0.0
nm	max	127.164	-	4.565	-	4.013	-	3.264	-	0.0
2014-02-19	max	125.601	99%	4.627	101%	4.328	108%	3.652	112%	5.0
2014-02-20	max	182.365	145%	5.171	112%	4.936	114%	4.429	121%	1.0
2014-02-21	max	188.933	104%	5.170	100%	4.932	100%	4.377	99%	1.0
2014-02-22	max	175.578	93%	5.084	98%	4.866	99%	4.231	97%	7.0
2014-02-23	max	181.307	103%	4.981	98%	4.734	97%	4.044	96%	1.0
2014-02-24	max	189.406	104%	4.873	98%	4.591	97%	3.813	94%	0.0
2014-02-25	max	164.814	87%	4.726	97%	4.324	94%	3.638	95%	2.0
2014-02-26	max	152.178	92%	4.519	96%	3.734	86%	2.975	82%	5.0
2014-02-27	max	149.250	98%	4.576	101%	3.478	93%	2.931	99%	0.0
2014-02-28	max	128.255	86%	4.563	100%	3.265	94%	2.597	89%	2.0
2014-02-01	min	80.791	93%	4.389	100%	0.427	100%	-2.018	108%	0.5
2014-02-02	min	61.558	76%	4.378	100%	0.364	85%	-2.267	112%	0.0
fm	min	63.285	103%	4.480	102%	0.156	43%	-2.344	103%	0.0
2014-02-04	min	53.492	85%	4.378	98%	0.232	149%	-2.648	113%	0.0
2014-02-05	min	57.868	108%	4.454	102%	0.211	91%	-2.747	104%	0.5
2014-02-06	min	58.320	101%	4.429	99%	0.145	69%	-2.619	95%	0.0
2014-02-07	min	63.916	110%	4.447	100%	0.211	146%	-2.989	114%	0.5
2014-02-08	min	65.104	102%	4.450	100%	0.247	117%	-2.813	94%	0.0
2014-02-09	min	62.215	96%	4.433	100%	0.156	63%	-2.776	99%	0.0
2014-02-10	min	64.082	103%	4.428	100%	0.126	81%	-2.582	93%	0.0
2014-02-11	min	61.700	96%	4.408	100%	0.086	68%	-2.381	92%	0.0
2014-02-12	min	57.871	94%	4.406	100%	0.156	181%	-2.080	87%	0.0
2014-02-13	min	61.268	106%	4.453	101%	0.156	100%	-2.004	96%	7.0
2014-02-14	min	n	-	n	-	n	-	n	-	0.5
2014-02-15	min	n	-	n	-	n	-	n	-	0.0
2014-02-16	min	n	-	n	-	n	-	n	-	6.0
2014-02-17	min	n	-	n	-	n	-	n	-	0.0
nm	min	114.202	-	4.521	-	0.789	-	-2.857	-	0.0
2014-02-19	min	80.682	71%	4.402	97%	0.533	68%	-3.124	109%	5.0
2014-02-20	min	10.022	12%	4.445	101%	0.676	127%	-2.916	93%	1.0
2014-02-21	min	46.276	462%	4.307	97%	1.009	149%	-2.967	102%	1.0
2014-02-22	min	47.257	102%	4.496	104%	0.921	91%	-3.348	113%	7.0
2014-02-23	min	95.609	202%	4.491	100%	0.936	102%	-3.011	90%	1.0
2014-02-24	min	123.550	129%	4.497	100%	1.115	119%	-2.560	85%	0.0
2014-02-25	min	128.198	104%	4.426	98%	1.060	95%	-2.395	94%	2.0
2014-02-26	min	130.466	102%	4.397	99%	0.936	88%	-2.564	107%	5.0
2014-02-27	min	86.083	66%	4.350	99%	0.548	59%	-1.710	67%	0.0
2014-02-28	min	84.797	99%	4.404	101%	0.441	80%	-2.212	129%	2.0

Fig. A_B2.13
water dynamics table - February 2014

Fig. A_B2.14
water dynamics chart - January 2014



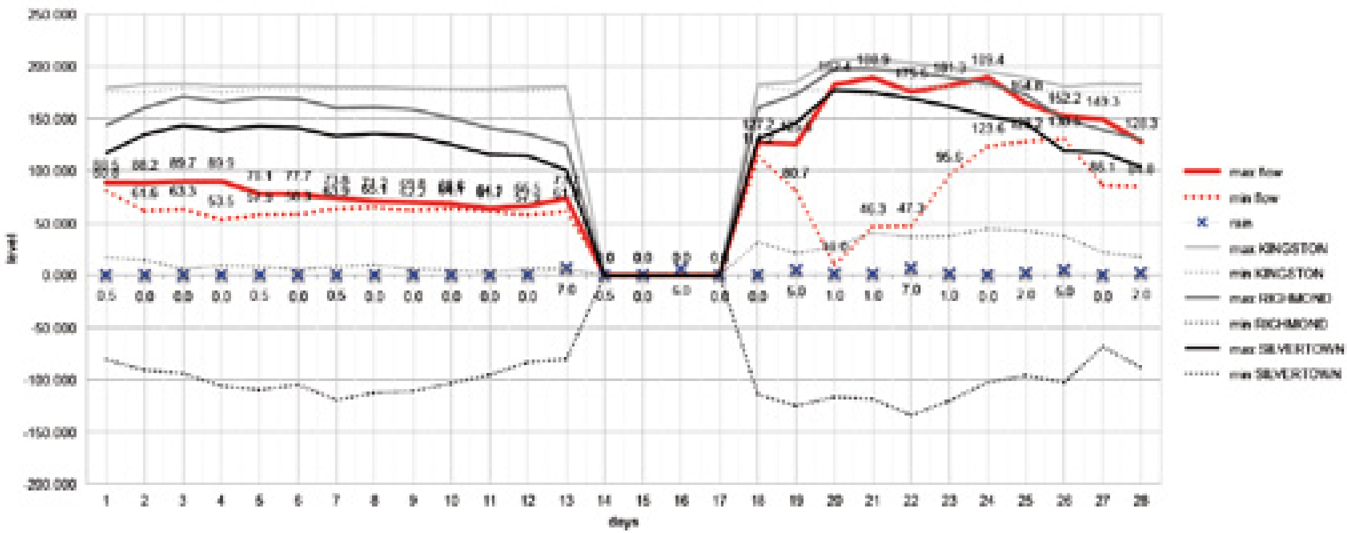


Fig. A_B2.15
water dynamics chart - February 2014

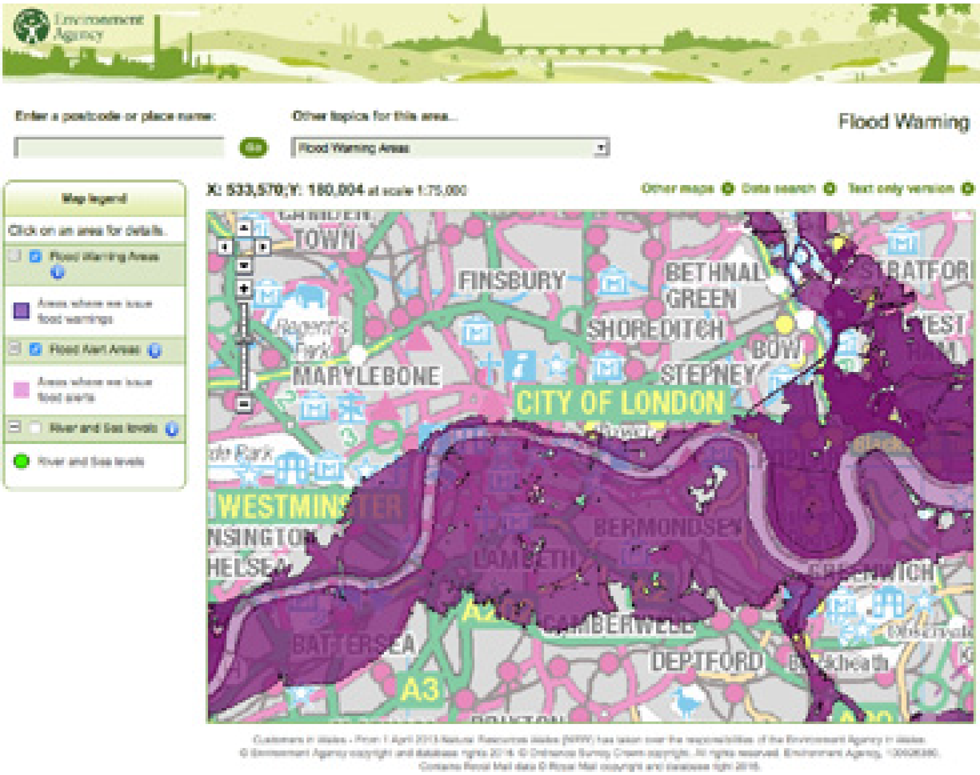


Fig. A$_B$2.16
Online map of the *Flood Warning and Alert Areas*.
(http://maps.environment-agency.gov.uk)

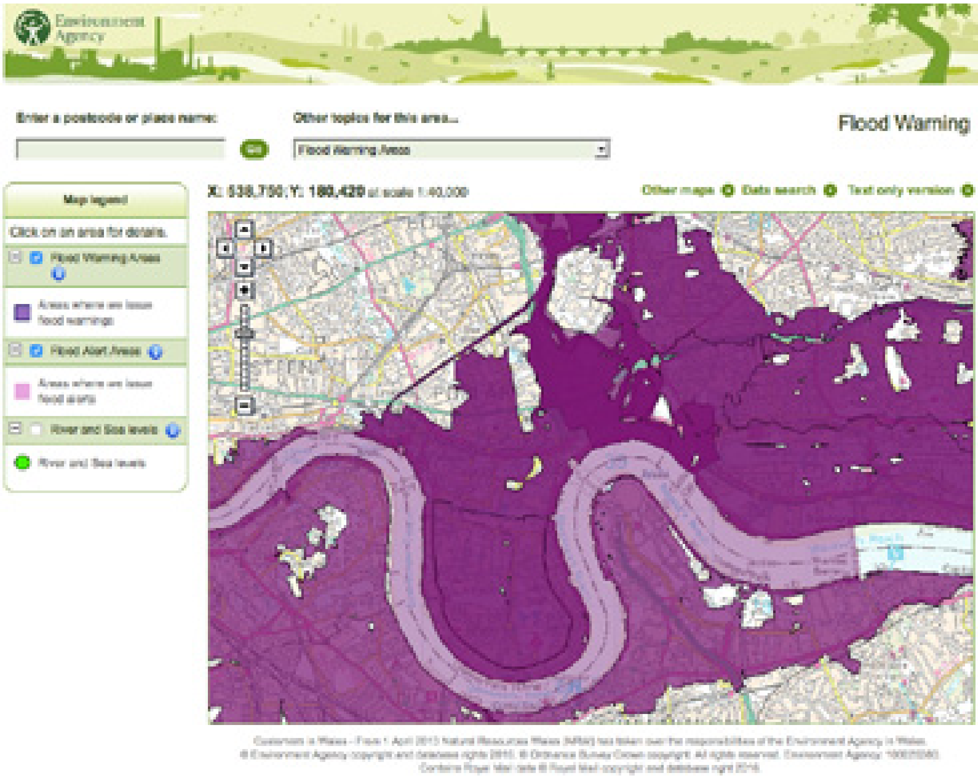


Fig. A_B2.17
Online map of the *Flood Warning and Alert Areas*.
(http://maps.environment-agency.gov.uk)

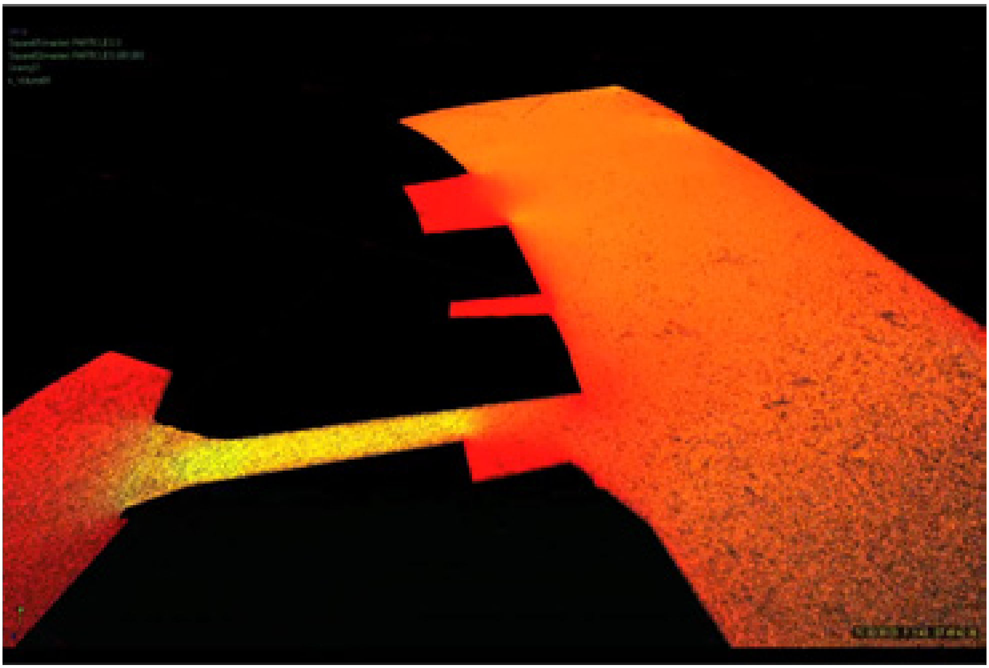


Fig. A_B2.18
Simulation on *Realflow* of water dynamics along the River Thames, in the pilot case area.

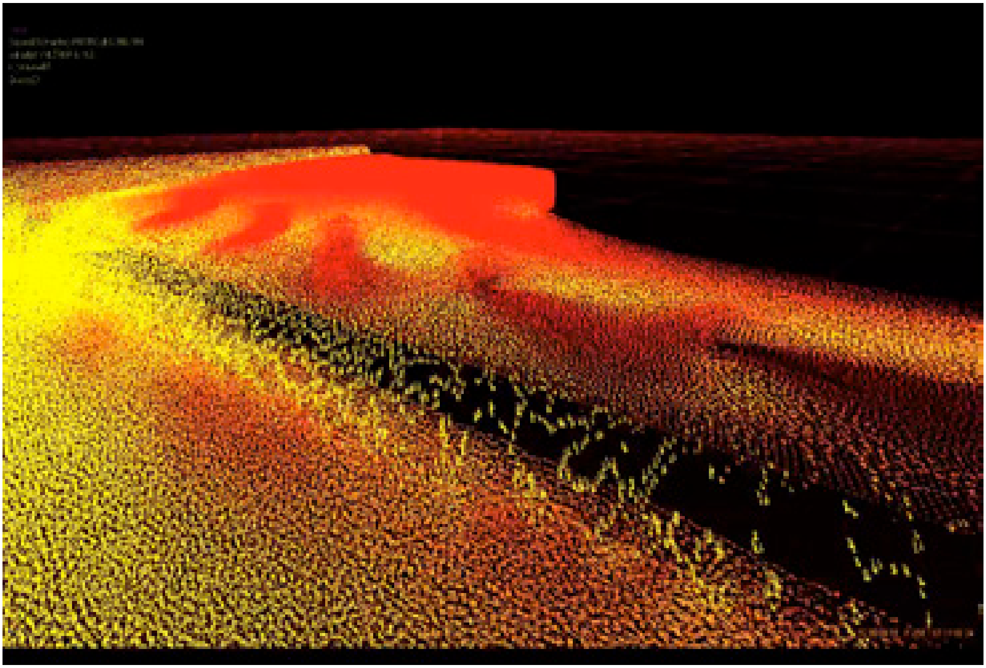


Fig. A_B2.19
Simulation on *Realflow* of water dynamics in a new canal of the River Lee, in the pilot case area.

A_B3. Real time people's location

The innovative characteristic of the *Telematic Map of Risk* is to correlate information regarding water dynamics and people's location over time. Having determined the *Flood Warning and Alert Areas* (based on geomorphological features and river's flows), the geo-referentiation of people is obtained via geo-located posts on Twitter. To do so, a plug-in of *Grasshopper—Mosquito*—is used. Through its tools one can identify tweets within a chosen radius. The smaller the radius, the larger the amount of data collected. Thus, a grid of circles is created onto the FWAA. Each point corresponds to any person who writes a Tweet in a precise location, in a specific time.

The complex script on *Grasshopper* has the centre of all the survey locations in the centre of the Thames Barrier, which is identified as point '0' of the system. People's geolocation has been projected onto the map in a ten-days period. This has allowed for a complete monitoring of areas' use, and a sufficient number of points to guarantee high quality analysis. The correct position of the cloud of dots and the *ArcMap* platform has been double checked through the triangulation of three point on the map.

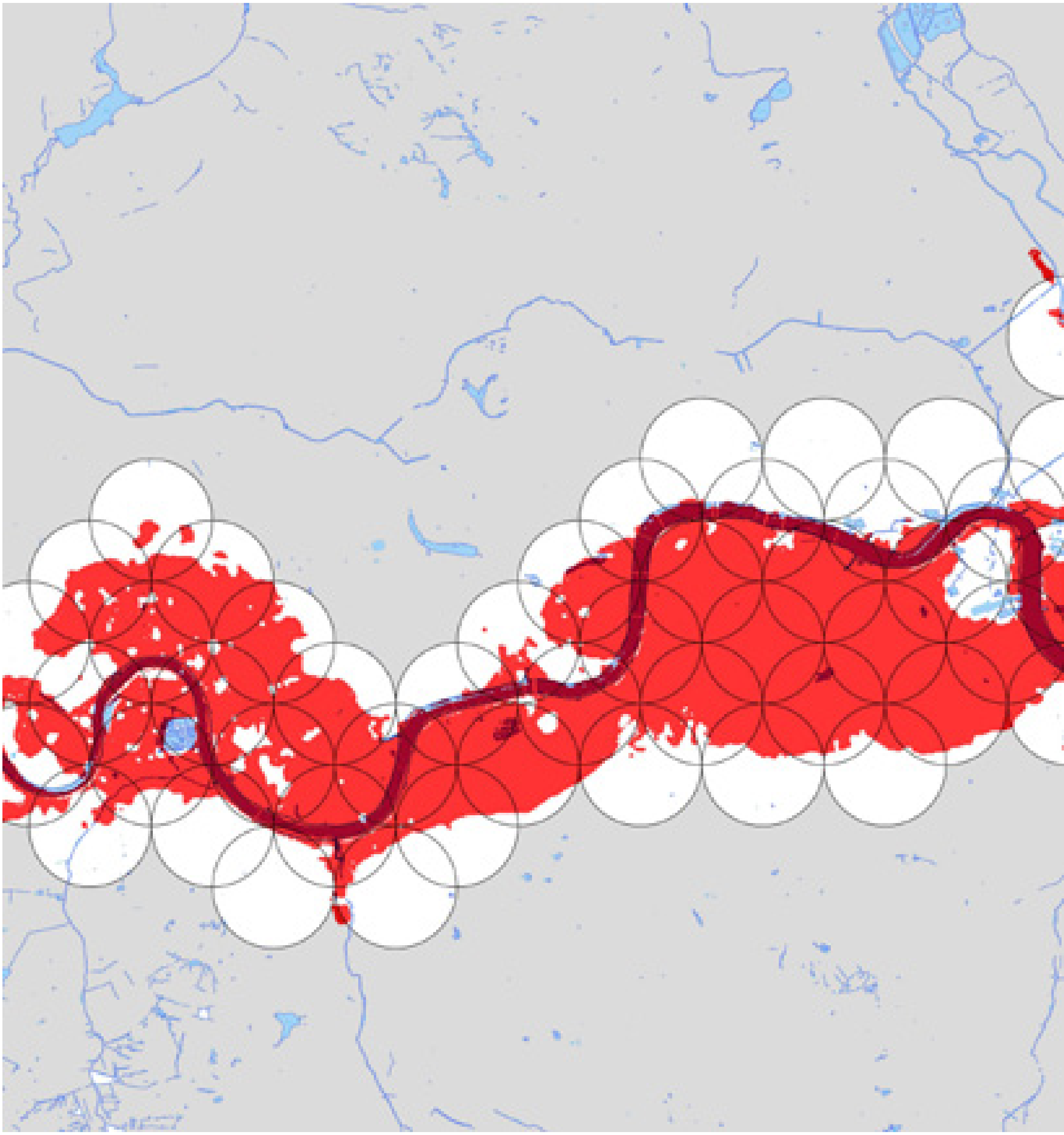
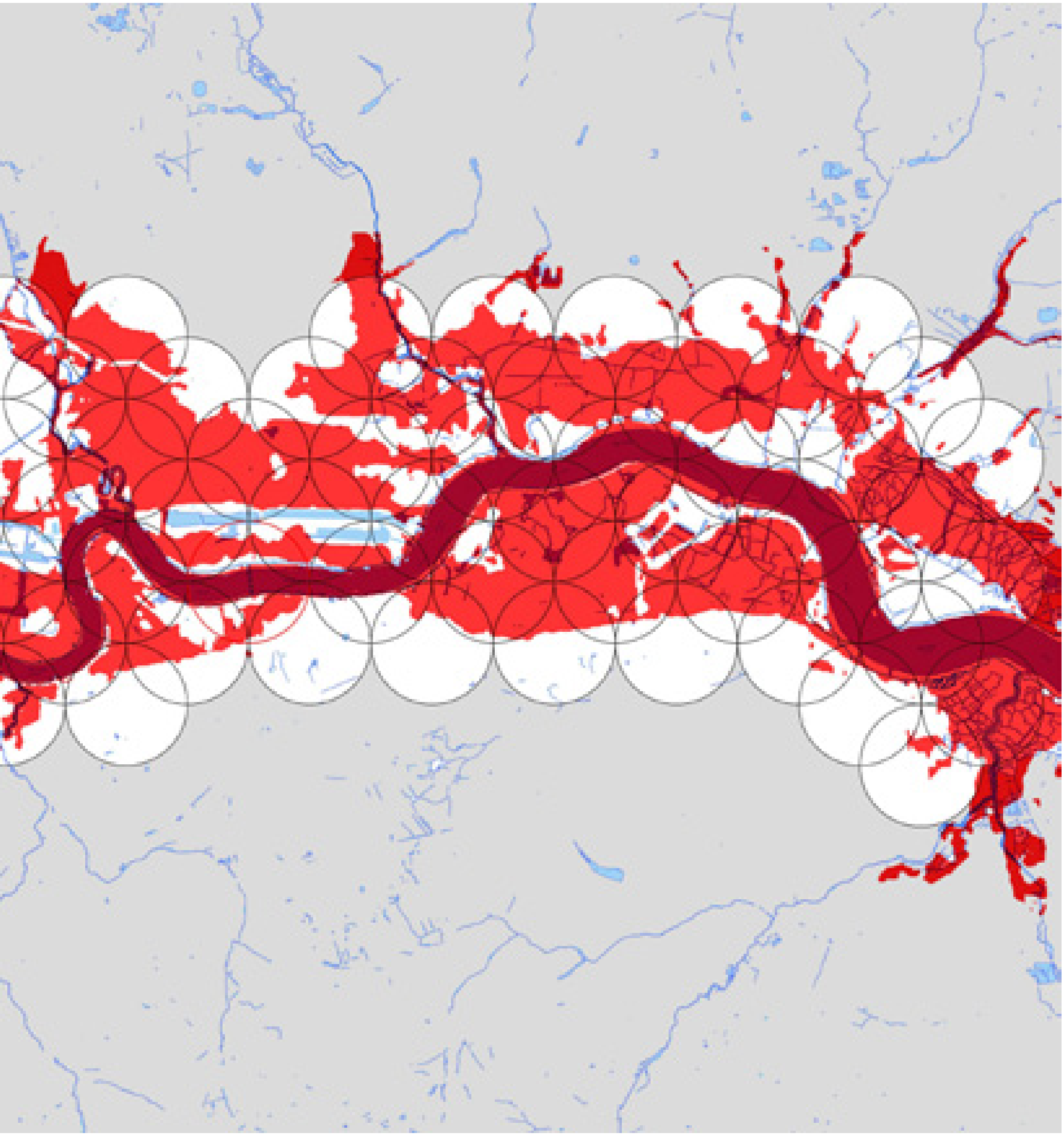


Fig. A_B3.1
Circles system for the extraction of geo-referenced points, matched with the *Flood Warning and Alert Areas.*



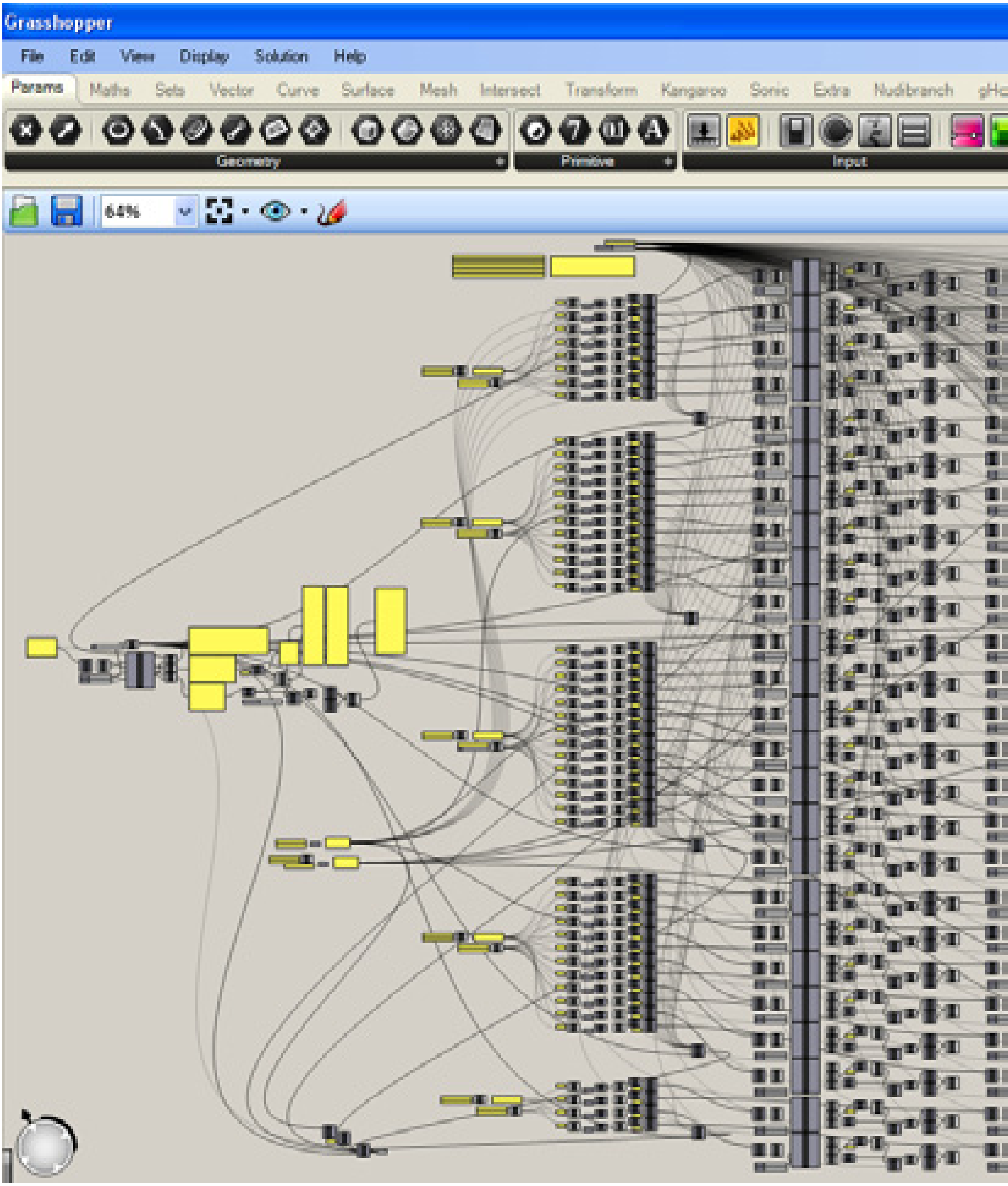
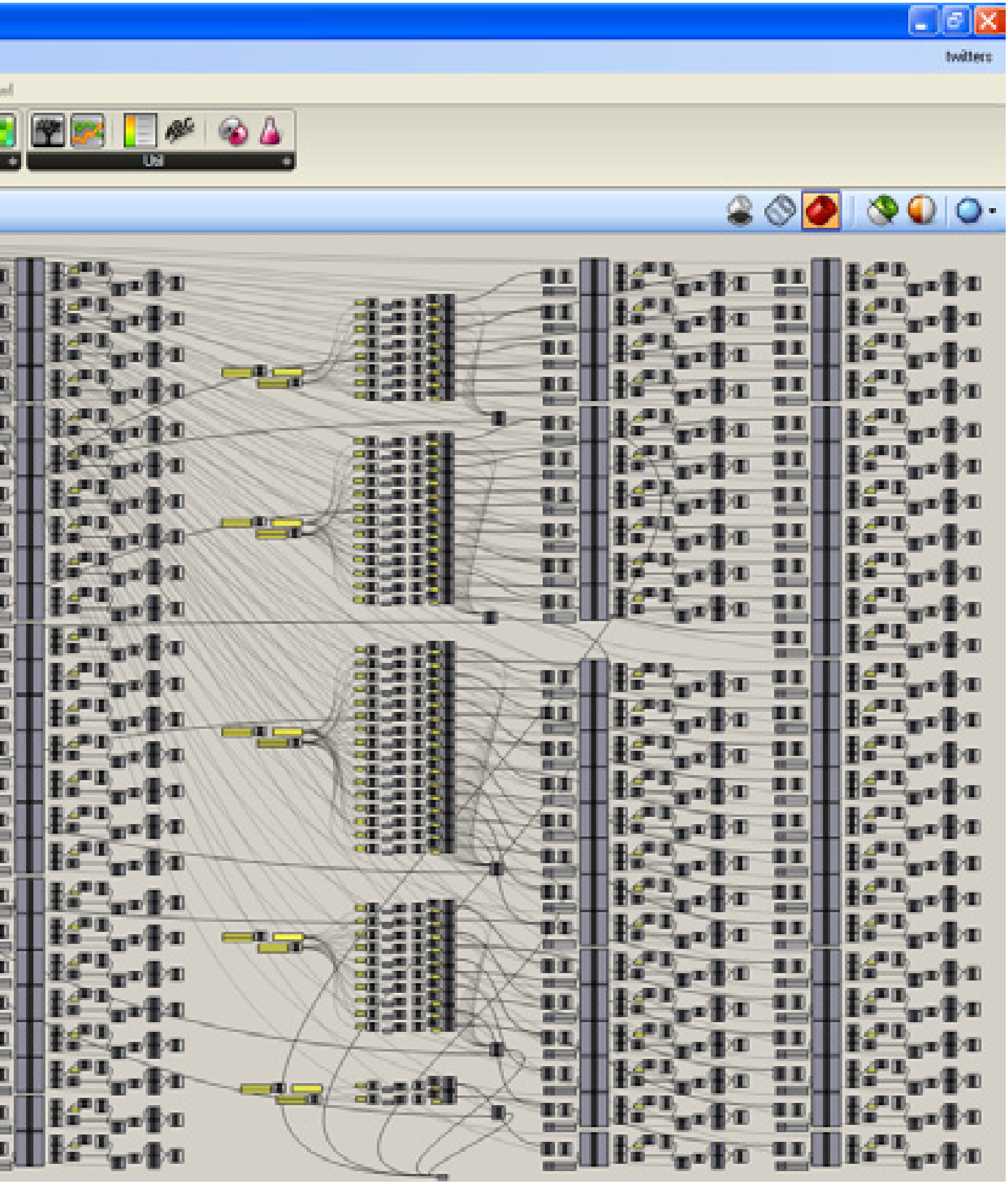


Fig. A_B3.2
Rhino-Grasshopper script setting the parameters for Twitter's data extrapolation.


twitters
Util

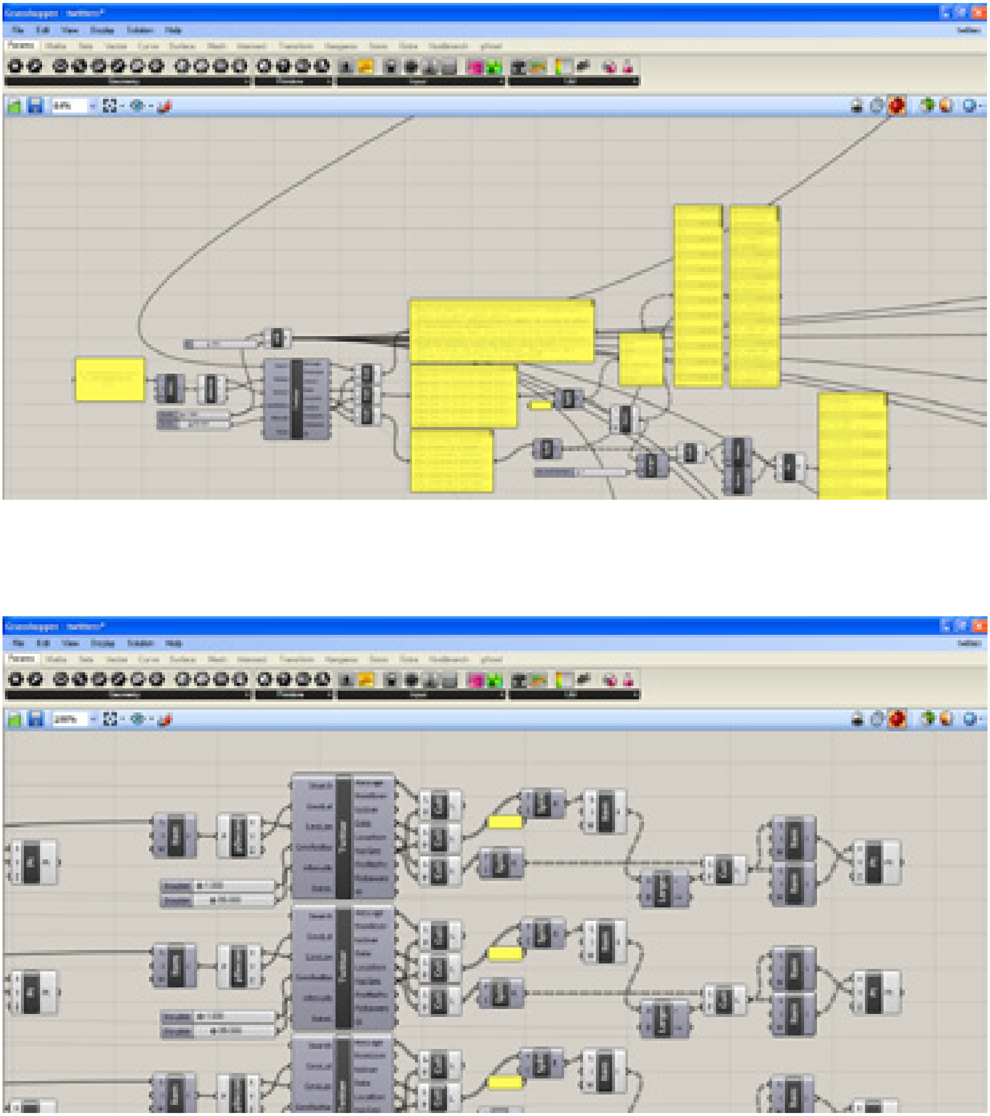


Fig. A_B3.3a,b
Rhino-Grasshopper script. Zoom on the ‘0’ point and the standard system of one extraction circle.

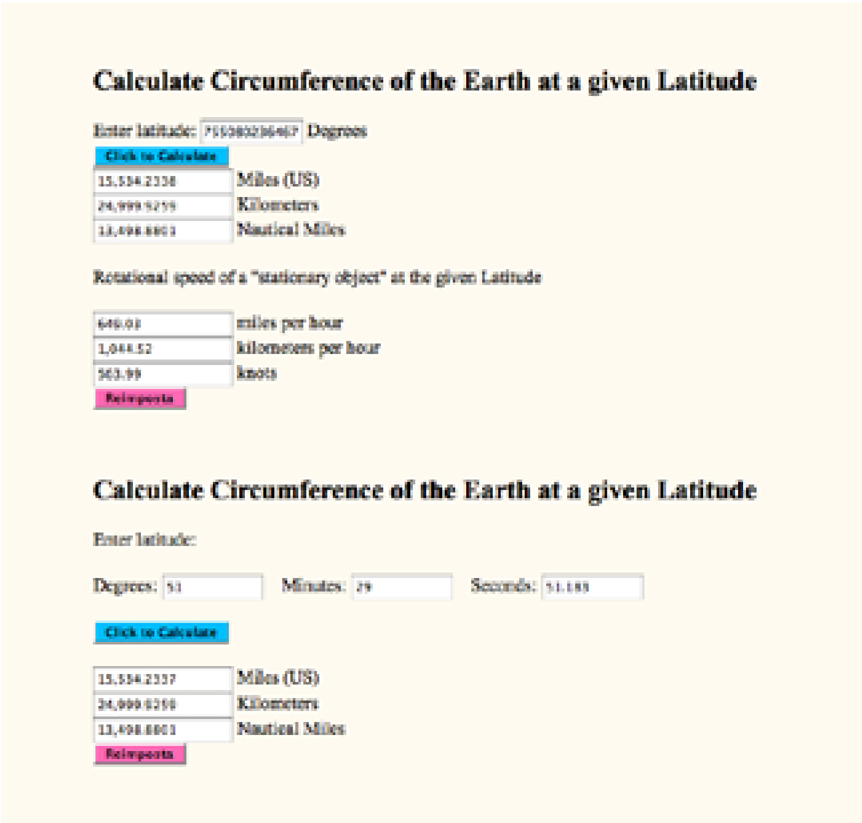


Fig. A_B3.4
Earth calculations to set the '0' point on the Thames Barrier.

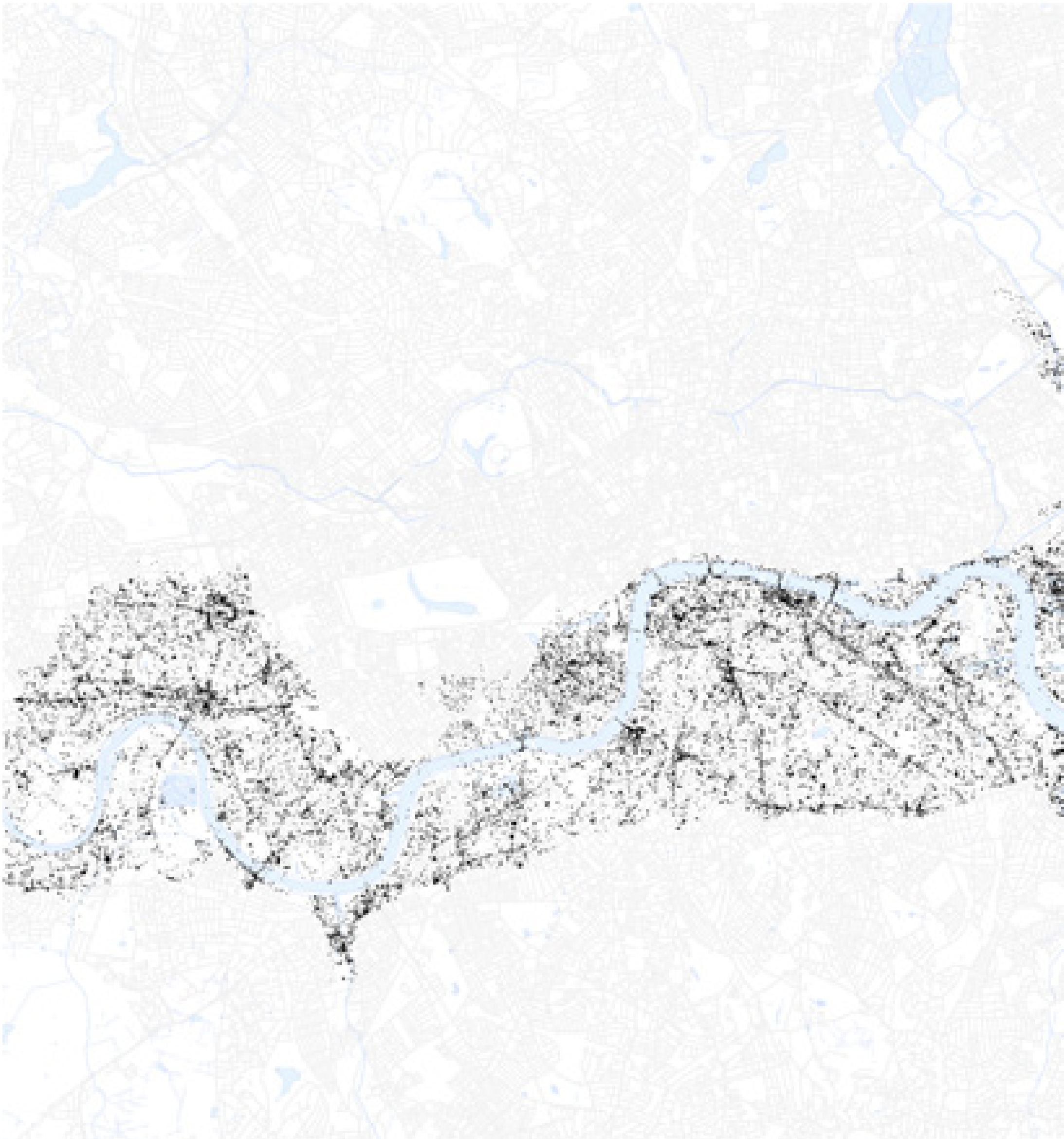
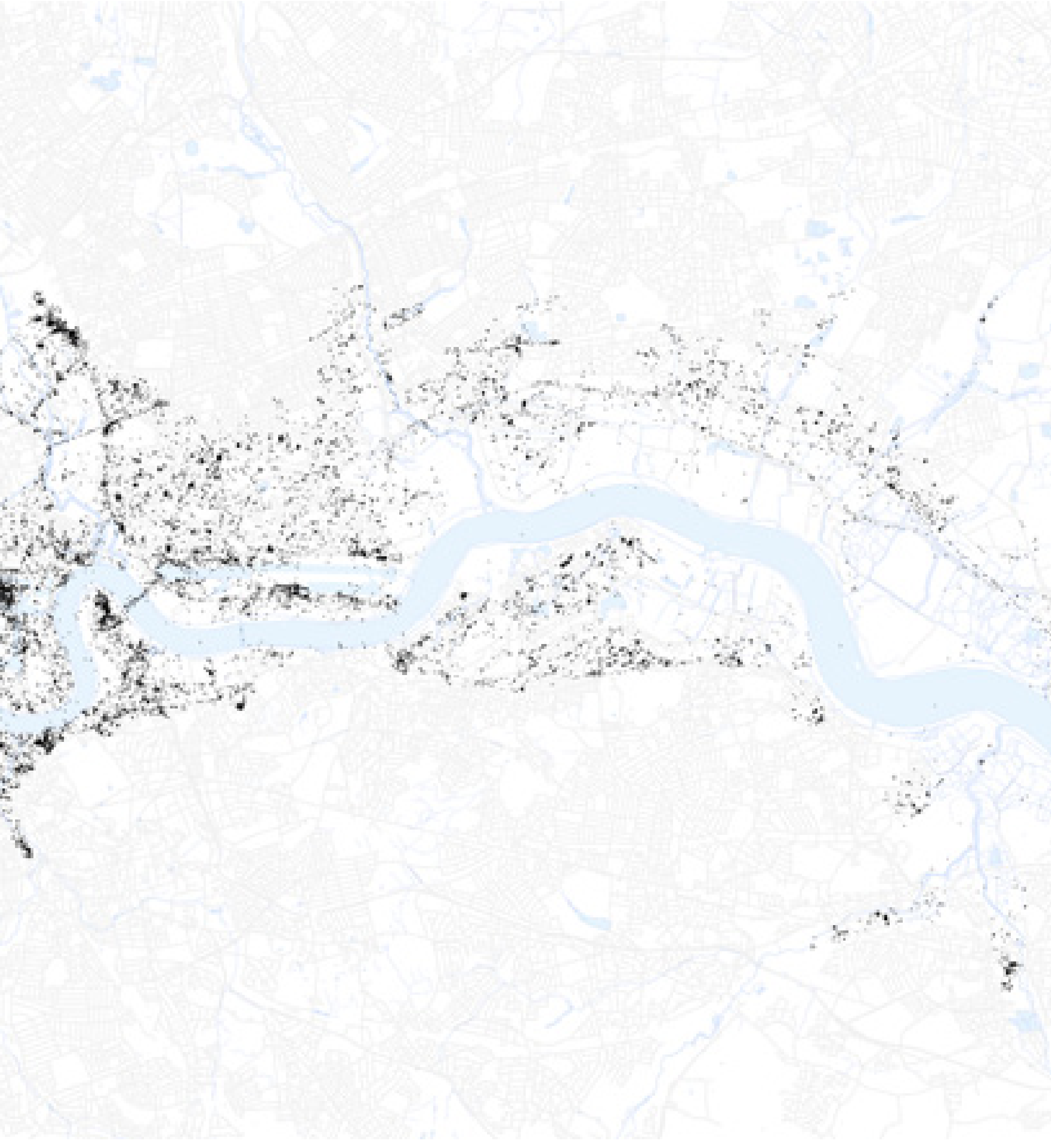


Fig. A_B3.5
People's location withint the *Flood Warning and Alert Areas*.



A_B4. Sketches and thoughts

This Section collects some of the many concept maps, thoughts, drawings regarding urban and architectural analysis, and methodological steps sketched during the development of the thesis.

Fig. A_B4.1
Considerations regarding the crucial points of the SWOT analysis.

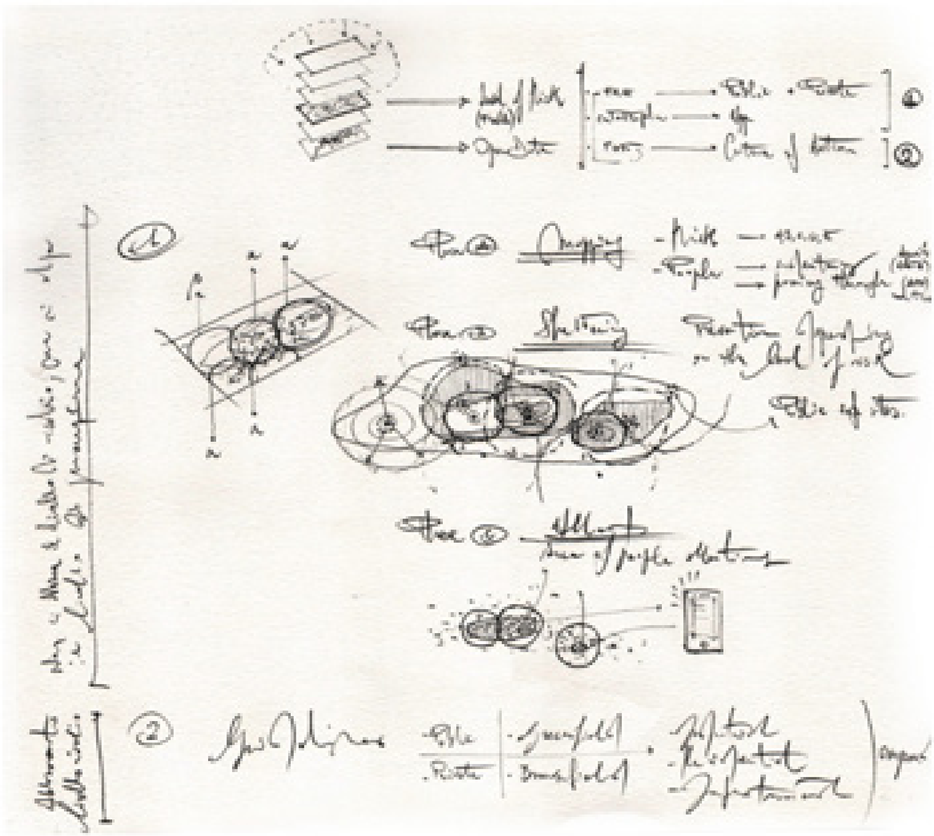


Fig. A_B4.2
Schemes on prevention and alert.

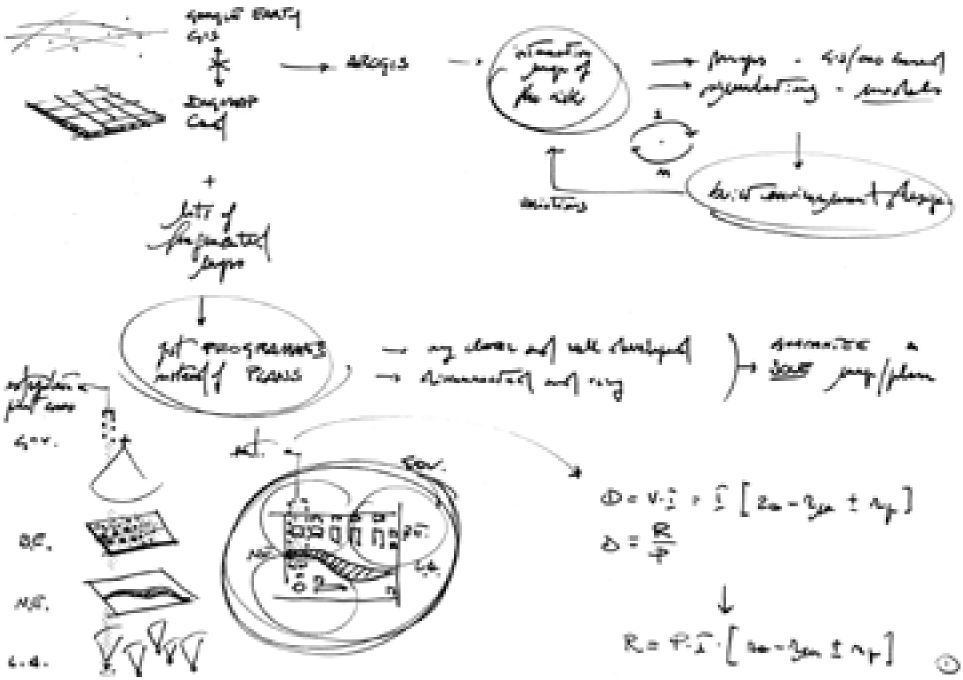


Fig. A_B4.3
Relationships between top-down and bottom-up approaches to design, and the role of simulation and modelling.

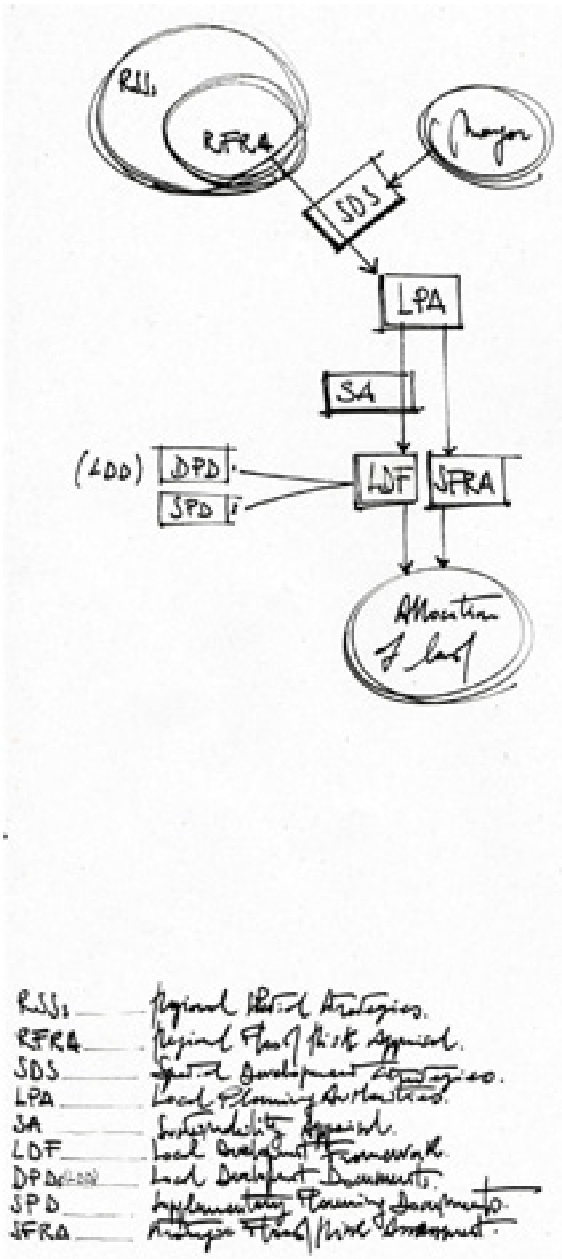


Fig. A_B4.4
Actors and stakeholders, and documents to allocate land.

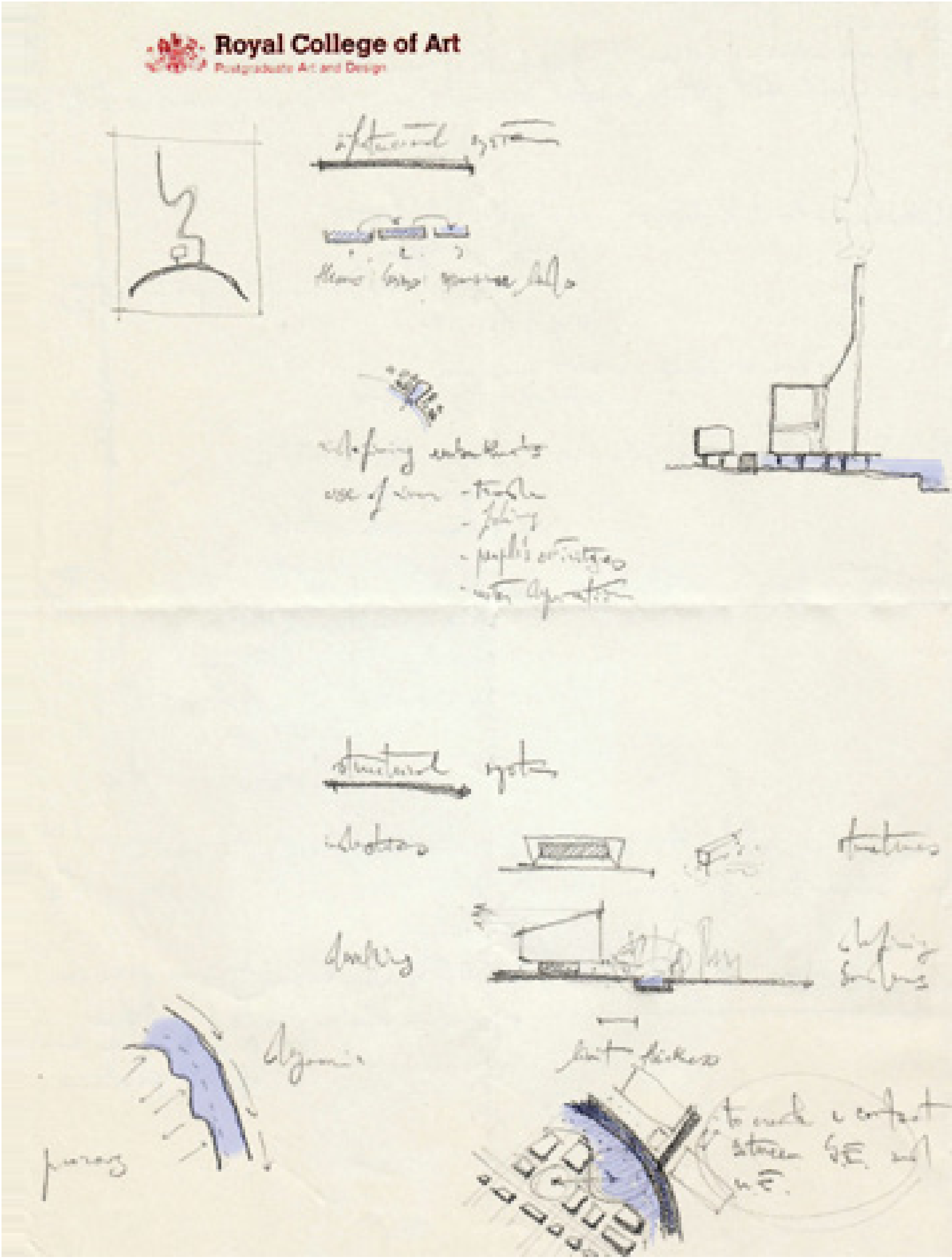


Fig. A_B4.5
Studies on industrial sites and residential areas of the pilot case.

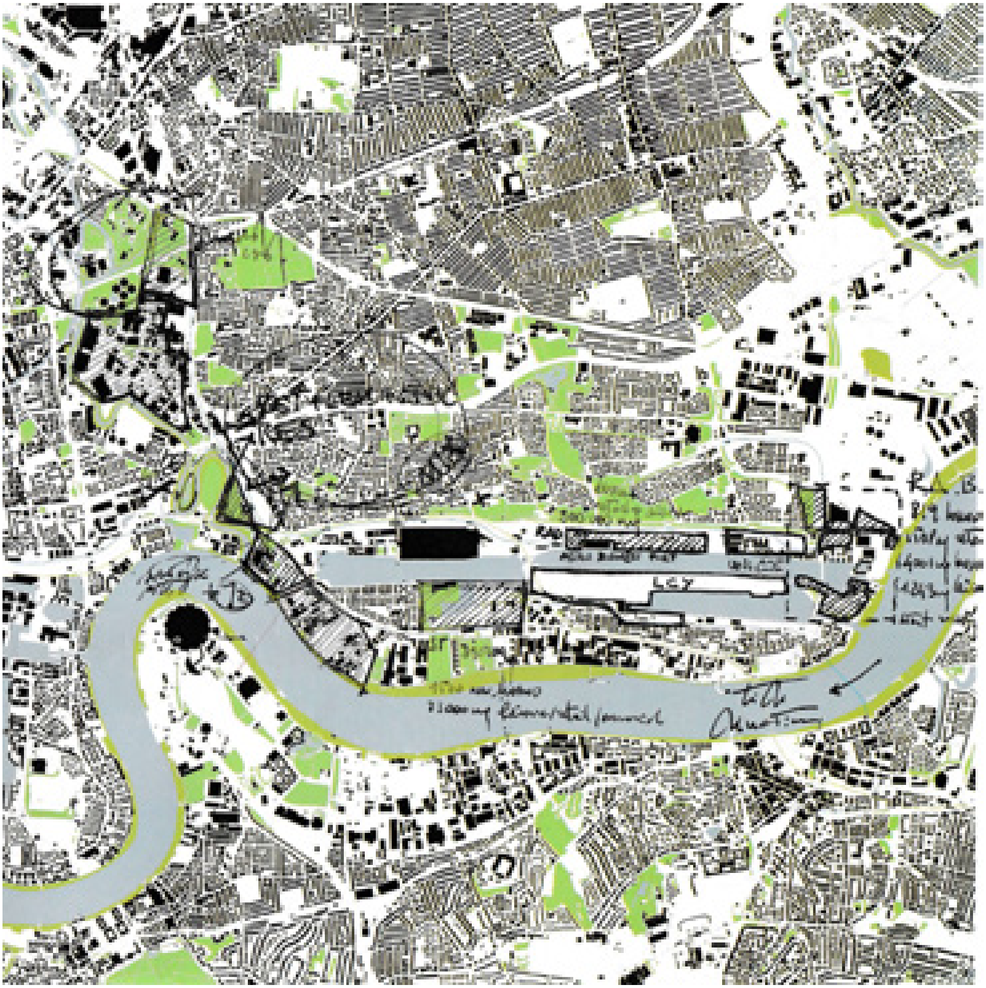


Fig. A_B4.6
Studies on industrial sites and residential areas of the pilot case.

Fig. A_B4.7
Studies on boundary areas of the pilot case.

Fig. A_B4.8
Studies on boundary areas of the pilot case.

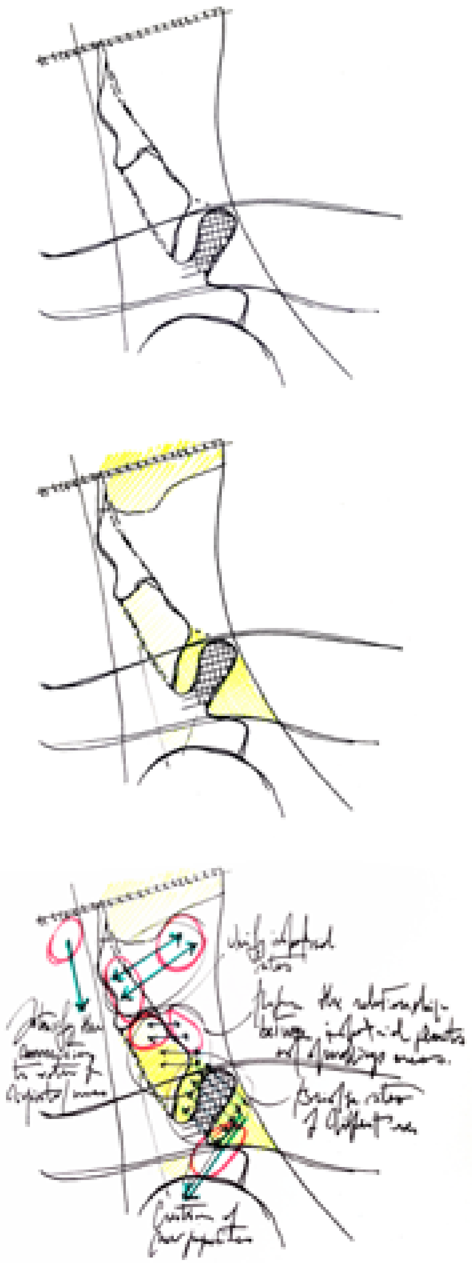


Fig. A_B4.9
Studies on spatial features and connections on the pilot case area.

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- http://www.worldbank.org/en/topic/waterresourcesmanagement

- http://www3.imperial.ac.uk/digital-economy-lab/partnernetworks/dce

LIST OF FIGURES

Main international corroboration of the research outcomes:

December 10-13th, 2014

48th International Conference of the *Architectural Science Association*

ASA / ANZAScA

'ACROSS: Architectural Research through to Practice'

Prof. Fausto Novi – Host, DSA University of Genoa

Prof. Mark Luther – ASA Vice-President, Deakin University

Dr Francesca Madeo – Conference Chair (ASA Board)

Title of the paper published: Beyond Water. Infrastructural Prevention from Flooding.

November 5-7th, 2015

1st International Conference on Anticipation

UNESCO

'Project Anticipation'

Prof. Roberto Poli – Conference Chair; Host, University of Trento

Committee: John Crowley, Keri Facer, Garry Jacobs, John Kineman

Title of the paper to be published: The *Telematic Map of Risk*. Big data and environmental flexibility design.

February 5th, 2016

International Conference Design After Planning

University of Westminster

'Examining the Shift from Epistemology to Topology'

Lindsay Bremner – Department of Architecture, University of Westminster

David Chandler – Department of Politics & International Relations, University of Westminster

Robert Cowley – Department of Politics & International Relations, University of Westminster & Department of Geography, King's College London

Isis Nunez Ferrera – Faculty of Architecture & Built Environment, University of Westminster

Tudor Vilcan – Department of Politics & International Relations, University of Southampton

Title of the paper to be published: Constructing uncertainty. Use of data for the design of disaster-resilient cities.

"Reality is merely an illusion—albeit a very persistent one."

Albert Einstein

printed in Ferrara (IT), March 2016

MATERIALISING RESILIENCE

OPEN DATA MANAGEMENT, FLOOD RISK ASSESSMENT AND OPERATIVE ACTIONS FOR DYNAMIC CITIES