MODELING PLACE ATTACHMENT USING GIS

by

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Abstract

The *PlaceInGIS* project is a comprehensive examination of how places can be represented using modern Geographic Information System (GIS). After decades of research, geographers now understand that places are dynamic features, whose fuzzy boundaries change over time, subject to internal and external forces. The long-term goal of the PlaceInGIS project is to make people's understanding of place visible, comparable and amenable to analysis.

Place attachment is a theoretical construct that permits the quantification, visualization and analysis of the importance of place. The method described makes use of two significant sub-components of place attachment, place dependence and place identity, to create fuzzy surfaces in a GIS.

After conducting a detailed GPS mapping exercise of the Colliery Dam Park study area in Nanaimo, British Columbia, Canada, 302 study participants were presented with a survey questionnaire between 2011 and 2012. The place attachment and place dependence components for each feature described were used to create "feature surfaces." These were then combined using a Fuzzy OR operator to generate a single "place attachment surface" for each individual, which can be compared against each other or summed to show the overall opinions of groups.

In the short term, we are developing an application called the Place Analysis System (PAS), which enables places to be adequately represented. There are numerous applications for the PAS, as it creates a foundation for the comparative study of place. For the first time, it is possible to visualize, take measurements and analyze place attachment. What was once an

ephemeral concept has been made concrete and amenable to study. The PAS can analyze fuzzy boundaries, or the fuzzy boundaries can be defuzzified to be more compatible with traditional representations of data in a GIS. We examine two applications of the PAS, one as a tool for site planning, and the other for the geographical analysis of core and periphery. These applications demonstrate the utility of the PAS, and we conclude by considering further applications and modifications to make the method easier to employ in future studies.

Lay Summary

What place is most important to you? Perhaps the neighborhood where you grew up or a beautiful park has a special meaning and is part of your identity. Can you explain its importance to other people? If this place were threatened, would you have the tools to explain its importance and convince others to preserve it?

The *PlaceInGIS* project was created to develop tools to understand better how and why places work. The project's first creation, the *Place Analysis System* (PAS), analyzes place attachment, the identity and dependence that important places produce. The PAS is a Geographic Information System (GIS) application to collect place information, display models of place on a computer monitor and allow them to be compared, combined and analyzed. It takes concepts that are difficult to explain and gives them shape, allowing them to be used for the description, defense, and planning of places.

Preface

This project, including the identification and design of the research program, the performance of the research, and the analysis of the research data was conducted in its entirety by Bradley David Maguire, with the exception of the data collection phase of the project. From October 20, 2011 to September 29, 2012, Vancouver Island University work-op students Stuart Dixon and Christopher Mueller assisted with the data collection for this project.

The UBC Behavioral Research Ethics Board issued certificate H11-00682 (minimal risk) on August 25, 2011 for the project "Representing the Importance of Place in GIS" under which this data collection was conducted.

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List of Abbreviations

BC: The Province of British Columbia, Canada

CC: Creative Commons

ESRI: Environmental Systems Research Institute, Redlands, California, USA

FMRI: Functional Magnetic Resonance Imaging

GIS: Geographic Information System

GIScience: Geographic Information Science

GPS: Global Positioning System

HBC; HBCo: Hudson's Bay Company

LiDAR: Light Detection and Ranging

PAS: Place Analysis System

PAEK: Polynomial Approximation with Exponential Kernel

PGIS: Participatory Geographic Information System

PPGIS: Public Participation Geographic Information System

SQL: Structured Query Language (Standard Query Language)

SSHRC: Social Sciences and Humanities Research Council of Canada

UBC: The University of British Columbia (Vancouver)

VBA: Visual Basic for Applications: Microsoft's interpreted form of the Visual Basic Language

VB.Net: A form of Microsoft's Visual Basic that is compiled within the .Net environment.

VIU: Vancouver Island University (Nanaimo)

Glossary

α-cut (alpha-cut): All values in a fuzzy surface that are greater than an arbitrary threshold value (α).

ArcGIS: The brand of Geographic Information System sold by the Environmental Systems Research Institute (ESRI), on which the Place Analysis System is based.

Artificial Boundary: A discrete, two-dimensional boundary that is laid out on the ground and is frequently demarcated by survey markers, signs, fences or border posts. Areas defined by artificial boundaries are frequently hierarchical (e.g. national, state/provincial, county/regional, city/municipal), and at each level of the hierarchy often form tessellations, i.e. they abut exactly and no area is left unaccounted for.

Attribute Join: An attribute join, in which a list of unique identifiers in one table (a key) is matched with the same identifiers in another table, allowing the rows in the table to be matched and temporarily connected together. Joins permit data from one table to be accessed from another table. In the PAS, the 9-digit participant number is commonly used as a key to join tables.

Awareness Distance: The distance at which attention focuses on a feature as a study participant approaches it. This represents the zone within which the feature is dominant over other competing features under most circumstances.

Centroid: The mean center (i.e. mean X, mean Y) of all the points that make up a feature.

Concatenation: The combination of all slices beginning at α and ending at the topmost slice. It includes all fuzzy surface values greater than α. Concatenations are numbered from the minimum slice up to and including the maximum, such that Concatenation_6_9 includes slices 6, 7, 8 and 9.

Constrained Centroid: If a line or polygon is irregularly shaped, the mean center of all the points that make it up may lie off the line, or outside the polygon. This is particularly the case when polygons or lines are "U" shaped. For single points, the mean center is always located exactly at the location of the point, so this problem cannot occur. The constrained centroid alters the location of the centroid so that it lies exactly on the line or within the polygon.

Feature Level: The stage of analysis between the raw data provided by the study participants and the production of the summed surface.

Feature Surface: A decay surface that is created for individual features that are mentioned by participants. Because a "feature" may have multiple components, the shape of the feature surface for them can be quite complex, but all have a single place attachment and distance value.

First Nation: The preferred term for the aboriginal or "Indian" residents of British Columbia.

Fuzzy OR: One method for combining fuzzy surfaces. The fuzzy OR function takes the maximum of two surfaces when they intersect, creating a single resulting surface that features the highest values of the input surfaces.

GeoDesign: The symbiotic merging of planning activities with advanced GIS based tools that are able to support the dynamic, interactive nature of planning activities. GeoDesign brings planning from the world of paper into the digital universe, facilitating tools and forms of analysis that were not previously available to planners.

Georeferencing: Precisely locating a feature on a map using latitude and longitude or the Cartesian coordinates of a projected coordinate system. A feature that is georeferenced is precisely and unambiguously located at a single place on the Earth's surface.

Map Algebra: A technique for manipulating raster data by with algebraic statements that use raster names instead of variables. The algebraic statements are usually applied between overlapping pixels on the rasters.

Monotonic: A relationship between two variables in which the curve never reverses direction; it either increases or remains flat, or it decreases or remains flat. Monotonic relationships never change from increasing to decreasing or vice-versa.

NoData: A special pixel value used in ESRI software to represent areas where data are not available. This should not be confused with a pixel value of 0, which is a valid pixel value (e.g. the elevation of sea level, or the slope of a horizontal surface).

Orthophotograph (Orthophoto): An aerial photograph that has been adjusted so that features appear in their correct mapped locations. Orthophotographs remove relief distortion to make the photograph planimetric.

Place Analysis System: An add-on software package for the ESRI ArcGIS 10.3.1 software environment that is used for entering, storing, visualizing and analyzing data about place.

Place Attachment: The strong bonds that people develop for particular places. Place attachment has two main components: place dependence and place identity (Williams & Vaske, 2003).

Place Attachment Surface: A surface created from the combination of all feature surfaces defined for a participant. The place attachment surface provides an overall description of the place attachment for the study area, as understood by a particular study participant.

Place Attachment Surface Level: The level of analysis between the generation of the feature surfaces and their combination into a single place attachment surface for each participant.

Place-Based Nomenclature: A technique for using the names of important features and places when discussing them with study participants, but matching these names with the precisely located features to allow the study participants to precisely locate the features on a map.

Place Dependence: "…the importance of a place in providing features and conditions that support specific goals or desired activities" (Williams & Vaske, 2003, p. 831).

Place Identity: "…the symbolic importance of a place as a repository for emotions and relationships that give meaning and purpose to life" (Williams & Vaske, 2003, p. 831).

PlaceInGIS.com: The website (http://www.PlaceInGIS.com) that supports the public outreach activities of this project.

Simulated Annealing: An optimization technique that begins by allowing large fluctuations in the input variables, and which gradually reduces the fluctuations allowed. For each set of input values provided, a suitability function calculates a value representing the quality of the answer obtained with the inputs provided. By starting with large fluctuations and gradually reducing them, the procedure is able to avoid local minima in the surface produced by the inputs, and then it can optimize to obtain the best answer.

Slice: A portion of the volume of a fuzzy surface starting at beginning α value and ending below (but not including) the succeeding α value.

Structured Query Language: Also known as Standard Query Language, SQL is a language for creating, modifying and updating the data in relational database management systems.

Subjective Boundary: A fuzzy boundary that is created by people. These often exist solely as mental maps, and are the product of place attachment, otherwise known as "a sense of place."

Summed Surface: A surface that is created by summing a number of place attachment surfaces, to describe a group consensus position.

Summed Surface Level: The level of analysis between the generation of the place attachment surfaces and their summation into a summed surface. Any combination of place attachment surfaces may be combined, according to different sub-groups (based on gender, weather, demographics etc.).

Theory-Based Interpolation: The interpolation of data points based on some underlying theory, such as the decay of memory over distance.

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Many people have offered help, support, and encouragement over the years, without which, this work would not be possible. In particular, I would like to thank my wife Brenda, who has made this possible with her unwavering support.

The good people of Nanaimo, some of whom graciously volunteered to take part in my survey, and the City of Nanaimo, which supplied data and advice, allowed this research to happen.

Vancouver Island University deserves recognition for providing the initial encouragement for me to undertake my Ph.D. The university offered me a sabbatical and a period of unpaid leave so that I could pursue my research. After I made the decision to switch to part-time employment, VIU graciously offered many course sections so that I could continue to support my family financially. Special thanks go out to the VIU Work-Op program and Student Research Assistants Stuart Dixon and Chris Mueller, who assisted with the collection of data.

Finally, many people have reviewed software functionality, papers and chapters including my Ph.D. Committee, its chair Dr. Brian Klinkenberg, and a number of anonymous reviewers who provided fresh perspectives on my work. My family, including my sister Susan Maguire (editor *extraordinaire*), Graham Maguire, Karla Hennig, Sandy Maguire and Steven Janssens also offered a great deal of assistance. Thank you for all your help; and of course, the errors that remain belong to me alone.

Dedication

For Jocelyn, who has never known a father who is not a student. May you learn the value of dedication, focus and creativity; may the sacrifice of your father's time benefit you long into the future.

Chapter 1: Using Geographic Information Systems for Place Studies

Sinan Aral (as cited in Kitchen, 2014, p. 128) states, "Revolutions in science have often been preceded by revolutions in measurement." The invention of the telescope, microscope, electron microscope and functional magnetic resonance imaging scanner all augmented humanity's capabilities, but the corresponding revision to our conception of humanity's place in the universe took some time to follow. Today, we are dealing with the simultaneous introduction of multiple technological innovations that are only beginning to change how we see the universe.

Two new technologies are revolutionizing our understanding of place. The first is the ongoing advance in computer technology, in particular mobile computing technologies and improved modeling techniques. Through the introduction of increasingly powerful computers, we are moving into an era when previously unsolvable optimization problems can be answered. We have moved far beyond what human beings can model, such that model-based science is now able to make accurate predictions in many fields, including computational biology, weather and climate. The second is development of a better understanding of how humans navigate and position themselves in the world. The 2014 Nobel Prize in Physiology or Medicine was won by John O'Keefe, May-Britt Moser and Edvard I. Moser for their discoveries of where locational and navigation information are stored in the brain, and how these cells are used for navigational purposes (Nobel Media AB, 2014). The development of functional magnetic resonance imaging (FMRI), which, for the first time, allows non-invasive observations of the inner workings of the human brain (Sanders & Orrison, 1995) is contributing to this improvement in our understanding of how the brain works. Taken together, these new technologies make it possible to create detailed computer models of how people see the world.

Kitchen (2014) points out that some fields of study, such as physics, work within a single scientific paradigm (Kuhn, 1970), whereas others, such as human geography, have multiple, competing paradigms. Geographers have advanced beyond the era when quantitative geography promised a "scientific" foundation for geography based on positivistic physical principles. Gray (as cited in Kitchen, 2014, p. 129) sees that we have moved into an era of "exploratory science" characterized by enormous volumes of information, statistical exploration and data mining. This new scientific era, which followed the era of "computational science," promises to revolutionize data-intensive fields of study such as geography. Geography has been limited by a dearth of mechanisms for analyzing large volumes of data. In the exploratory science era, new high-density data collection techniques, such as Light Distance and Ranging (LiDAR) and sophisticated analytical methods driven by high-performance computing may finally fulfill the objectives of the quantitative geographers by using new techniques that are more appropriate for the subject matter. Not only do we have the means to collect and analyze geographical data effectively, but we also have the wisdom to understand those analyses effectively through many different paradigms to advance geography as a science.

This dissertation describes the development and use of the ***Place Analysis System*** (PAS), a computer system that stores, models, visualizes and analyzes people's perception of place, making place tangible and usable in comparative research for the first time. Using the PAS, we can now see the parts of places that are valued by particular user groups. Moreover, we can compare and contrast what areas are valuable to different groups, allowing us to understand *where* they may agree and disagree.

Appleton & Lovett (2005) point out that visualizations (including maps) are one of the few methods of communications that transcend educational limitations. We also argue that they also transcend linguistic and cultural differences. While this dissertation looks at hyper-local data, the methods can be scaled to solve regional or international issues as well. Thus, the PAS has the potential to help resolve longstanding disagreements over place, offering a new tool to help solve disputes.

1.1 From Space to Place

In 1981, I visited the Vancouver trade show of the Transglobe Expedition, Sir Ranulph Fiennes' three-year long north-south expedition around the world by land, sea and ice (Spindler, 2016). I was fascinated by the concept and the logistics involved, but dismayed that this expedition was billed as one of humankind's "last great adventures" (Transglobe Expedition, 1981). While certainly an adventure, it was not a true voyage of exploration, given that every significant location it went to had already been explored. The big budget, highly mechanized methods of transportation reinforced my perception, that while difficult and potentially dangerous, these adventurers were a long way from the deprivation that true explorers like Sir Ernest Shackleton had encountered 65 years earlier. The age of exploration was over, followed by a period of "filling in the holes" that the true explorers had left behind, traveling the last patches of the globe on which people had never set foot. In a sense, traveling over Earth's last untouched land surfaces began their conversion from "space" to "place."

This research project had its origins in my biography as it was affected by place. During many of my Father's exceedingly long road trips, we came upon places of exceptional and rare beauty, which cemented the importance of place into my consciousness, and led me to seek out ephemeral experiences of place.

I have always been drawn to places of exceptional beauty and this attraction has led me to ask what it is about certain places that makes them important to people. One of the places to which I have been drawn, my current residence in Nanaimo, was in part because of an experience that I had in Colliery Dam Park. While exploring different neighborhoods by bicycle for a place to live in Nanaimo, I emerged out of a glade of trees to encounter dozens of children swimming in the Lower Colliery Lake. Coming from Vancouver, B.C., I realized that I could afford to live a few blocks from a park of exceptional beauty, so I chose to live in the area.

Tim Cresswell (2004) points out that "place" is both a common word and a highly specialized one. People use the term in a general way during everyday conversation, but researchers use the term (often in the singular) to conceptualize an area with a history and meaning, as opposed to space, which is merely a meaningless location. Cresswell succinctly states the difference as "Places have space between them" (Cresswell, 2004, p. 8). Such an explanation is a little simplistic, because it is cast from the viewpoint of a human speaking at a particular point in time. There may be animals for which Cresswell's "space" is actually "home," a very important kind of place indeed. Furthermore, such a perspective is welded in time to the present day. What is now space may have been an important place in the past and what is an important place today may be meaningless in the future.

Langer (1953) emphasizes the meaning inherent in place, pointing out that even space itself may change, as long as the meaning remains.

> …a ship constantly changing its location is nonetheless a self-contained place, and so is a gypsy camp, an Indian camp, or a circus camp, however often it shifts its geodetical bearing. Literally we say a camp is *in* a place, but culturally it *is* a place (Langer, 1953, as cited in Relph, 1976, p. 29).

It is easy for a Geographic Information System (GIS) operator to analyze spaces without consideration of their meaning as places. Today, Geographic Information Science (GIScience) is working at being able to characterize places effectively, preserving their significance and meaning.

1.2 What Is Place?

Place has many different connotations, based on how the word is used. As a specialist term, it depends on the background and discipline of the person using it (Cresswell, 2004). For decades, anthropologists (e.g. Augé, 1995), geographers (e.g. Massey, 1994; Pred, 1984; Relph, 1976; Tuan, 1977), philosophers (e.g. Casey, 1998; Malpas, 1998), psychologists (e.g. Dornič, 1967; Ekman & Bratfisch, 1965), tourism scholars (e.g. Kneafsey, 1998), urban planners (e.g. Hayden, 1995; Zukin, 1993) and others have struggled to define what a place is and where place boundaries occur. Accordingly, there is a rich body of research on this topic. Despite the enormous amount of effort and creative thought that has gone into understanding place, researchers who study place are still far from having a complete understanding of it.

Nonetheless, significant progress has been made. There is a spectrum of views on the topic, but Cresswell (2004) divides the literature into a "reactionary" tradition and a "progressive" tradition. The progressive tradition is arguably more comprehensive in scope, has a longer-term perspective and is less anthropocentric than the reactionary tradition. In the reactionary tradition, places are defined mainly in terms of their stability and resistance to change; they are thought to have definite boundaries and change slowly or not at all, and because of this, are undeniably "authentic" (Relph, 1976; Tuan, 1977; Augé, 1995; Harvey, 1996).

It is unfortunate that Cresswell chose such value-laden names for the two traditions. Using "dynamic" and "static" instead of "progressive" and "reactionary" might be better choices; these indicate that there is a spectrum of views, rather than exclusionary, value-laden opposites. It is easy to assume, from Creswell's given names, that the progressive tradition is necessarily a newer approach than the reactionary tradition, but both are thousands of years old. For example, in the second Century CE, Marcus Aurelius, wrote "Flux and change are for ever renewing the fabric of the universe. . . . In such a running river, where there is no firm foothold, what is there for a man to value among all the many things that are racing past?" (Marcus Aurelius, as cited in Harvey, 1996, p. 10). Compare this with Nigel Thrift, writing over 1800 years later, who states, "Places are 'stages of intensity', traces of movement, speed and circulation" (Thrift, 1994, p. 222). Both the ancient and modern perspectives demonstrate that places are ephemeral and subject to change. This interpretation implies that the boundaries of place are fuzzy: "No configuration of space-time can be seen as bounded. Each is constantly compromised by the fact that what is outside can also be inside" (Thrift, 1994, p. 223).

Place studies can be complicated because there are multiple concepts of place, coming from different intellectual traditions and having different foci. There have been many different conceptualizations for place, in particular those of Augé (1992), Pred (1984), Thrift (1994), Massey (1997) and Tuan (1977). Williams (2014) has subsumed and expanded on these concepts, to provide a comprehensive classification of the different ways of viewing place. Williams characterizes three main concepts, which he calls *ethnos, demos* and *bios*. These are not mutually exclusive; people rarely subscribe to only one of these concepts, and may find that their beliefs have elements of all three. Any nuanced discussion of place will show that all three views are present to some degree in any person's views of place.

Writers such as Augé (1992), who consider place to have authenticity based on decades or centuries of human occupation and layered meanings lean strongly towards *ethnos*. *Demos*, an ideal that allows both authenticity and rootedness while accepting cosmopolitanism and permeable boundaries, is a concept that shows up strongly in the work of Pred (1984), Thrift (1994), and Massey (1997). *Bios*, an ideal characterized by the concept of bioregionalism and libertarian ideals, can be found in the work of Tuan (1977) and in some of the comments by Pred (1984).

Each ideal has its archetype. For *ethnos*, this would be an isolated, traditional European village, such as Troina, Sicily (Fitzjohn, 2007). For *demos*, it would be a multicultural neighbourhood in a large city, such as Kensington, in London (Massey, 1997). For *bios*, good examples would be towns that derive their existence from their local environment, and thus are ecologically aware. Some examples might include Aspen, Colorado, West Yellowstone, Montana and Jasper, Alberta.

Ethnos is a traditional, conservative way of looking at place. It emphasizes the role of culture and shared history in the making of a place. Places are created over long periods by the actions of generations of residents. Thus, in this view, places gain authenticity over time.

Attempts to create new places may lack authenticity, and these may be relegated to the category of *non-places* (Augé, 1992). Augé contrasts these with places where tradition and history are paramount. He is an anthropologist, and the places that he deals with are sometimes literally *in situ*, as opposed to the present-day places that many human geographers study. Even though the study area surrounding the park was colonized by miners from the Europe (mainly the UK) and Asia less than 200 years ago, many participants evoked a sense of ethnos in their comments about the study area.

Demos is, in many ways, the opposite of *ethnos*. This concept celebrates the dynamic, interconnected, pluralistic and changeable nature of places, a concept that was introduced by Allan Pred (1984).

Pred's interpretation of place stresses the nature of a place as being a "historically contingent process," a product of both individual and institutional practices:

> Place is seen as a process whereby the reproduction of social and cultural forms, the formation of biographies, and the transformation of nature ceaselessly become one another at the same time that time-space specific activities and power relations continuously become one another (Pred, 1984, p. 279).

His emphasis on the power relations that are inherent in the creation, maintenance and destruction of places reminds us that places exist at the whim of both natural forces and human influences.

Nigel Thrift seems to cling to a sense of the authentic in his writing, while at the same time noting that the pace of change can be brutal. Thrift asks "What is place in this new 'in-between' world? The short answer is – compromised: permanently in a state of enunciation, between addresses, always deferred" (Thrift, 1994, p. 222). The pace of change can be frenetic: "Space… takes on critical importance as both a battlefield and a zone of mixing, blending, blurring, hybridizations" (p. 218). Thrift's characterization of the impact on places must sound dire to those who gravitate toward the *ethnos* ideal: It seems like the very nature of places is at risk, where "encroaching pseudo-places have finally advanced to eliminate places altogether" (pp. 222-223).

Doreen Massey leans strongly towards the *demos* ideal, establishing a bold, outward-looking, cosmopolitan perspective, with four characteristics:

1. place is not static, but is instead a process;
2. places do not necessarily have boundaries, but may be defined by what happens outside of them;
3. places are the site of multiple identities and histories, which may be in conflict with one another; and
4. a uniqueness of place is defined by its interactions with the outside (Massey, 1997).

Massey's *demos*-influenced view contrasts strongly with the *ethnos* ideal of place.

> Instead then, of thinking of places as areas with boundaries around [them], they can be imagined as articulated moments in networks of social relations and understandings, but where a large proportion of those relations, experiences and understandings are constructed on a far larger scale than what we happen to define for that moment as the place itself, whether that be a street, or a region or even a continent. And this in turn allows a sense of place which is extroverted, which includes a consciousness of its links with the wider world, which integrates in a positive way the global and the local (Massey, 1997, pp. 154-155).

The conclusion that Massey draws is that places do not need discrete boundaries; fuzzy boundaries work as well: "places do not have boundaries in the sense of divisions which frame simple enclosures… they are not necessary for the conceptualization of a place itself" (p. 323).

Bios is a concept of place that is based on bioregionalism, which emphasizes local, sustainable solutions to issues surrounding place. Like *ethnos*, *bios* can emphasize the "authentic," but in this case, the authenticity is based on ties to land and nature, rather than to a particular history. This work echoes and builds on some of the themes discussed in Pred (1984), particularly the connection between the individual, society and the environment in which he or she lives.

Yi-Fu Tuan (1977) also focuses on the internal characteristics of place, but in the context of the resources that they provide for humans and animals:

> Recent ethological studies show that nonhuman animals also have a sense of territory and of place. Spaces are marked off and defended against intruders. Places are centers of felt value where biological needs, such as those of food, water, rest and procreation, are satisfied (Tuan, 1977, p. 4).

Tuan turns toward an anthropocentric viewpoint when he states "what begins as undifferentiated space becomes place as we get to know it better and endow it with value" (p. 6), although the comment could equally be applied to any other animal that adapts the environment to meet its needs.

Not only are places sources and storehouses of resources, but they also have an emotional importance – Tuan believes that the comfort associated with having resources in a particular place is the source of a place's importance. It is the stability of places that imparts their value: "Permanence is an important element in the idea of place. Things and objects endure and are dependable in ways that human beings, with their biological weaknesses and shifting moods, do not endure and are not dependable" (Tuan, 1977, p. 140). Tuan's biological explanation for the importance of place helps to explain why places can be so controversial, particularly when they are perceived to be under threat.

The foundation of my research lies primarily within the work of Massey (1997) and Pred (1984), in particular the *demos* concept of place (Williams, 2014), which assumes that places are dynamic and change in response to natural and human forces. Colliery Dam Park's fuzzy boundaries are fluid, and can be shown to change over time in response to administrative decisions made by the City of Nanaimo, the actions of park users and other external events including the seasons. While the park has a core area, it also features a periphery that gradually gives way to adjoining places such as the community of Harewood and the (Vancouver Island) University District (see Figure 2.1, p. 44). While there is some sense of authenticity and a deep sense of place attachment among park users, as a public park, the area is not exclusionary in any way and reflects the multicultural nature of Nanaimo. In the words of one study participant, "It is the 'live and let live' park of Nanaimo." This inclusiveness means that the park is mostly outside Williams' *ethnos* concept of place. A lack of opposition to recent construction in the park, coupled with strong support for the preservation of the dams mean that the park is also largely outside the *bios* concept of place.

Of course, because of the cosmopolitanism of the park, there is a wide variety of opinions, and some people hold more tightly to the *ethnos* and *bios* concepts than do others. For the *ethnos* concept, the park has a strong historical component, and plays an important role in evoking memories, a sense of history and a sense of rootedness. Both the indigenous Snuneymuxw people of Nanaimo, who have used the region for centuries, and the European and Asian descendants of coal miners and other early settlers look to the park for a sense of place. For those who lean towards the *bios* ideal, the area helps to fulfill the need for contact with nature (biophilia), and the area contributes to the sustainability of Nanaimo in its role as a wilderness area and a provider of ecosystem services.

Depending on whether an individual gravitates toward *ethnos*, *demos* or *bios*, they may value a place in different ways and to different degrees. For many participants, however, there will not be a clear preference for one view over the others; the differences between these three views may not be identifiable in visualizations of different places.

1.3 The Need for Place

Places meet physical needs for both humans and animals. For a plant or a small, relatively immobile organism, destruction of a place (habitat) likely means death; for larger organisms, it may mean discomfort and years spent getting re-established in a new home. Tuan believed that the comfort associated with having resources in a particular place is the reason for their importance. "Animals, including human beings, pause at a locality because it satisfies certain biological needs. The pause makes it possible for a locality to become a center of felt value" (Tuan, 1977, p. 138). Tuan's biological explanation for the importance of place helps to explain why humans can have such a visceral reaction when they perceive a threat to important places.

Humans, with their ability to travel long distances on foot, can plan for such long journeys, and to extend our innate abilities with pack animals or mechanical transportation, are less affected by changes to place than most other animals. Of course, different people have different degrees of agency, and an individual's ability to move (or resist moving) is affected by his or her age (Dennis, 2006), experience, resources and education. Ultimately, however, there are a limited number of places left to go, a reality that we face in a globalized world.

Humans are also different from other organisms in that our needs are supported by a hierarchy of places, from home to the nation state, and indeed, the entire planet. For humans, like other organisms, a home is a place of shelter, a storehouse of supplies, a place of rest and procreation. Home is highly personalized and a location for socialization and entertainment for humans, unlike for other organisms. A neighborhood offers humans other opportunities for socialization, but also a place to ask for help and borrow supplies or tools. Well-established neighborhoods, such as Beacon Hill in Boston (Tuan, 1977) may also offer a sense of permanence, with the presence of old, architecturally distinct buildings, traditions and public rites, and historical events. Neighborhoods may be segmented by social status – in less privileged neighborhoods, it may be difficult to obtain basic requirements for living, such as quality food (Diao, 2014), whereas in affluent neighborhoods, there may be many grocery stores and shops to meet most needs. Communities offer communal resources, such as hospitals, police stations, sources of water, waste disposal facilities, specialized stores, parks and recreation facilities, places of work and sources of specialized labor. At the national level, governments promote the economic and physical well-being of all through the promotion of international trade, and the provision of collective defense. Increasingly, we are aware of the planet as a whole because of the importance of resources such as the atmosphere and oceans, which now suffer from a range of transnational environmental problems.

Tied to these hierarchical levels of home, neighborhood, community, nations, and the planet itself are a whole range of indirect and conceptual reactions. People may physically benefit from each type of place, but each may evoke a range of beliefs and emotions, something that largely separates humans from other organisms. The home is a place to which feelings of safety and pride are often associated. We have many phrases in our language which reflects this emotional tie to home: "home sweet home," "his home is his castle," "home is where the heart is," "home for the holidays." In some cases, however, the emotional connection to home can be a negative one, as Manzo (2005) reminds when she describes how battered women may seek special places outside the home. A neighborhood evokes a sense of shared interests and aspirations. The community may be a source of civic pride, especially when this is encouraged through local festivals and parades. At a national level, patriotism may be encouraged through the singing of national anthems and visual displays of national symbols such as flags. Such displays may be encouraged by national governments, but they may also arise spontaneously, as Tuan points out: "Human groups nearly everywhere tend to regard their own homeland as the center of the world. A people who believe they are at the center claim, implicitly, the ineluctable worth of their location" (p. 149). Nationalistic responses are rarely stronger than when the survival of the nation is threatened, either by an external adversary or by natural disasters. In such situations, we see individuals willing to risk their lives for the survival of others. Many of us have now grown up with the idea of the Earth as a fragile "pale, blue dot" (Sagan, 1980), and we may soon see strong reactions, not only to our nations, but also towards the planet itself in the face of environmental threats.

In some cases, this hierarchy can be transcended by education, religious belief or telecommunications. For the privileged, a university education may lead to friendships with individuals from different parts of the world who have different beliefs. For an even smaller number of the most privileged, opportunities for international travel and business may bring frequent contact with people from other countries.

Inexpensive and increasingly widely distributed infrastructure, in particular the synergistic combination of solar power, LED lighting, inexpensive computers, and the smart phone, is leading to a revolution in communication, education and collaboration. This is one factor driving globalization. People living in remote villages in the third world can now communicate with the centers of power in the developed world, in theory bypassing many levels of the hierarchy described above. While meaningful communications of this form are still relatively rare (we will ignore telemarketers and numerous unsolicited e-mails for the moment), they are changing places in the developing world. Remittances from family members in the developed world to members in the developing world are changing international monetary flows. The influence of the family members in the developed world is also changing the nature of places. Massey (1997) described her neighborhood of Kensington, in London, and its many connections with the outside world that made it such an interesting place.

Places are important to all living organisms (Tuan, 1977). Simple organisms are tied to place in a way that is difficult for human to conceive of, but as organisms gain in agency, they are less tied to single places. For humans, the same rule applies; those with the most agency have the greatest ability to travel (Branting, 2014) and are less tied to the conditions present in particular places. Human society presents us with an imperfect hierarchy of places, including home, neighborhood, community, nation state, and increasingly, the entire planet. Each level provides different resources, and is valued for different reasons in different ways. Although humans are not entirely alone in having emotional reactions to place, we are the only species that we know of in which the emotional aspects of place are of similar importance to the physical aspects. People's reactions to threats to particular places may be strong, and in extreme cases (such as in time of war), people may be willing to give their lives for the preservation of that place.

1.4 Why Place Is Difficult To Study

Place, like many concepts in the social sciences, is an extraordinarily complex phenomenon. Many different disciplines including geography study place; each brings its own concepts, jargon and epistemologies to bear on the subject. Part of the reason for this broad base of research on the topic has to do with the complexity of the subject, some of which will be discussed here.

First, place is spatiotemporal. Although changes tend to occur slowly, human intervention can alter a place beyond recognition in a matter of days. Even without drastic human intervention, geophysical and biological processes act to change places slowly. In a few decades, most evidence of human occupation disappears unless a place is actively maintained by its inhabitants. The interplay of human and natural changes results in a state of flux; unless the human and natural changes are finely balanced, places change over the course of decades. For researchers, this makes the understanding of place difficult, as it is a moving target, and may have evolved beyond recognition before their data have been processed.

Although the spatiotemporal nature of place makes its representation within a GIS challenging, it does not preclude its analysis. All data entered into the PAS is tagged with its time of collection, so it is possible to view the changes in place perception as they vary by time, season and weather condition.

Second, places exist within ecosystems, and are thus subject to local, regional and global changes, feedback loops and natural cycles. Nature exists as the dynamic interplay of the geophysical environment with billions of biological actors. Some of these organisms exist at different fractal dimensions from humans, as is the case with arachnids (Williamson & Lawton, 1991), such that they coexist with humans mostly without our knowledge. Because we are dealing with an ecological system, negative feedback loops normally encourage homeostasis, but if a system is interfered with sufficiently, positive feedback loops may lead to rapid changes of state. Thus, ecological components cannot be ignored if we wish to preserve the essential character of a place. In this way, those who have Williams' *ethnos* ideals may also appreciate his *bios* ideals. Without recognition of the ecological characteristics and ecosystem services provided, a place cannot be stable because non-human ecological changes can force human changes. A cogent example of this is the rapid spread of invasive species in Colliery Dam Park, including English ivy (*Hedera helix*), daphne (*Daphne laureola*), Scotch broom (*Cytisus scoparius*), English holly (Ilex aquifolium) and Himalayan blackberry (*Rubus discolor*). These are now the subject of sporadic clean-up efforts by the City of Nanaimo and volunteer groups.

Third, places are fuzzy in nature, and their boundaries challenge many European concepts of land tenure and demarcation. Harris *et al.* point out that many GIS databases have been based on artificial boundaries derived from the existing cadaster (Harris, Weiner, Warner & Levin, 1995). Research on cognitive mapping has shown that people do not think of places in

Cartesian terms (Kitchin and Blades, 2002). Because a participant's conception of a boundary may not coincide with the legal definition (Brunckhorst & Reeve, 2006; Jorgensen & Stedman, 2011), ignoring physical boundaries can provide better understanding of the behavior of park users.

When examining travel routes, however, physical barriers are important and should be modeled. The strength of the barrier is dependent on the species; while humans can read warning signs and barriers are sized to prevent human travel, birds and other animals may be able to cross the barriers with relative ease. To create the *barriers* layer, all fences in the *infrastructure_lines* layer were combined with local roads. This was then edited manually, so that crosswalks and overpasses allow for travel within the study area. As well, small features such as vehicle gates that are easily circumvented by animals or pedestrians were removed before this layer was used for data processing.

This research explains some issues that arise in planning. The multidimensional nature of cognitive maps allows for fuzzy places with overlapping boundaries that change dynamically. From the perspective of people whose properties adjoin the park, the phrase "Not in My Backyard" may be an honest expression of concern, as their subjective boundaries may extend well past their legal parcel boundaries (Brunckhorst & Reeve, 2006; Jorgensen & Stedman, 2011). Conversely, the boundaries of a place in a person's cognitive map may not extend as far as the legal boundaries of that place, opening up opportunities for the revision of artificial boundaries.

The fourth reason why place is difficult to study is that the psychology of place is complex. We deal with this in our discussion of boundaries in the next section and in Section 1.6, when we discuss the concept of Place Attachment.

1.5 Boundaries

There are a number of different classification systems for boundaries. Some of the main classification systems are described in this section, and we conclude with our own take on these – a dichotomous system that explains the two types of boundaries encountered in this study.

1.5.1 *Bona Fide* and *Fiat* Boundaries

Smith (1995) defines two types of boundaries that are found on maps. The first type of boundary is *bona fide.* According to Smith, "*Bona fide* boundaries are boundaries which exist independently of all human cognitive acts – they are a matter of qualitative differentiations or discontinuities in the underlying reality" (Smith, 1995, p. 476). Examples of *bona fide* boundaries are coastlines, heights of land, and rivers. Humans tend to appropriate these for use as jurisdictional boundaries for two reasons. Reason one is that such boundaries have strong geographical influences. For example, mountain ranges often separate different cultures or language groups. Reason two is that these boundaries are physically visible and require surveying only so that they can be placed accurately on a map. For the inhabitants on each side, there is no need for an official survey, since the feature naturally divides people into different groups.

Smith's second type of boundary is the *fiat* boundary, which is the result of "... acts of human decision or fiat, to laws or political decrees..." (Smith, 1995, p. 476). *Fiat* boundaries may be based on *bona fide* boundaries, or they may be arbitrarily defined on a map, prior to being laid out on the ground. Arbitrarily defined *fiat* boundaries are laid out when there are no *bona fide* boundaries to work with; these must first be defined on the ground by the surveyor using survey markers, and then they must be marked for the public by signs, fences or even walls. Many places, perhaps the most famous example being the western boundary between the United States and Canada, at 49 degrees north latitude, are still defined by nothing more than a series of easily visible survey markers.

Although cartographers, GIS technicians, planners, surveyors and developers are most comfortable with the idea of *fiat* boundaries around regions, the average citizen may be less enthusiastic with such a concept. Citizens may be more accustomed to thinking in terms of *perceptual regions*, which, according to Fisher, are "…the regions we actually live in, the city, the neighbourhood and the like. Neighbourhoods are not mapped on the ground..." (Fisher, 1996, p. 89). Fisher also defined *imposed regions*, which are regions surrounded by Smith's *fiat* boundaries, with the added requirement that these regions *must* be demarcated: "Imposed regions include all political and legal regions. These are clearly defined and have boundaries which are legally enforced and surveyed with measurable precision and accuracy on the ground" (Fisher, 1996, p. 89).

As an example of this, Brunckhorst and Reeve (2006) worked with residents in rural Australia and asked them to draw the communities of interest where they frequently traveled. They found that the *perceptual regions* actually used by people were significantly different from the *imposed regions* that were laid out before the automobile became the dominant form of transportation. Thus, it can be seen that *fiat* boundaries are arbitrary by nature, difficult to define, difficult to enforce, and subject to change if the assumptions under which they were drawn are altered. Characterizing places is often a daunting task. The qualities of place are sometimes ineffable; getting people to agree completely about *fiat* boundaries may be an impossible task, unless the extra steps are taken to create an *imposed region*.

1.5.2 Three Axes of Boundary Definition

Fuzzy boundaries are somewhat different from the traditional crisp boundaries used by planners and land managers. Thus, it is important to understand some of the characteristics of boundaries (Jacquez, Maruca & Fortin, 2000). Boundaries may be classified along three axes:

- **Crisp versus Fuzzy**: Crisp boundaries are infinitely thin, and separate different uniform areas. Lines on a map, which separate administrative areas, are a good example of crisp boundaries.[1] Fuzzy boundaries are imprecise, and represent the "degree of membership" of a particular property at any place. Such boundaries reflect the fact that natural features often graduate into one another, and a particular location along a fuzzy boundary may belong to one or more areas to differing degrees (Leung, 1987).
- **Closed versus Open**: Closed boundaries encompass areas having relatively uniform values, whereas open boundaries form a barrier on one or more sides of an area, but do not completely enclose it.
- **Natural versus Anthropogenic**: Natural boundaries are defined through non-human activities and forces, whereas anthropogenic boundaries have been defined through the actions of humans.

1.5.3 Artificial and Subjective Boundaries

If we take the axes defined by Jacquez, Maruca and Fortin (2000) and lay them out in a table, we can provide examples of the eight possible boundary variations that result (Table 1.1). From these eight possible kinds of boundaries, we find that two are particularly relevant in our study of Colliery Dam Park.

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[1] This theoretical discussion of the nature of boundaries is separate from a cartographic discussion of the precision of boundaries. From a cartographic perspective, a point that was collected with a precision of ±100m may be adequate for a 1:250,000 scale map, but will not be adequate for a 1:10,000 scale map.

Natural Boundaries		
	Crisp	**Fuzzy**
Closed	*Bona Fide* Mesas	Islands; Lakes
Open	*Bona Fide* Escarpments; Cirques	Foothills of a large mountain range; coastline of a continent[2]
Anthropogenic Boundaries		
	Crisp	**Fuzzy**
Closed	**Artificial Boundaries** *Fiat Boundaries* Defuzzified subjective boundaries; parcel boundaries; undisputed national boundaries; municipal boundaries	**Subjective Boundaries** Traditional lands of Aboriginal groups; boundaries of places
Open	*Fiat Boundaries* The land boundary between the United States and Canada	Disputed sections of national boundaries

Table 1.1. Examples of different kinds of boundaries formed by the three axes.

In this study, we contrast two types of boundaries. The first, commonly found in the world of the surveyor, are crisp, closed and anthropogenic. The second, formed by the perceptions of study participants, are fuzzy, closed but still anthropogenic. While the first kind corresponds with the Jacquez *et al.* (2000) definition of an ***artificial boundary***, the second kind has not been named. We term this a ***subjective boundary***.

Artificial boundaries are discrete, crisp, closed two-dimensional features that are defined by one or more experts. Those that lie at the same level of importance (e.g. national boundaries) are crisp, usually static, and generally do not overlap. Artificial boundaries may be invisible, visible on satellite images, as land use differences, or they may have been made visible on the ground by human actions, such as the surveying of a new subdivision or the construction of fences between lots.

Subjective boundaries are fuzzy, even though they are created by humans. Without fences or survey posts to mark them, boundaries between properties may only be known to within a

[2] On a map of the world, these features may be closed, but they are so large as to be effectively unending on the scale of the individual.

few dozen meters (often necessitating the employment of a surveyor to re-establish a discrete boundary). In addition to being fuzzy, subjective boundaries are contingent and dynamic, and may shift in response to changes in the physical environment or public opinion.

The dynamic nature of subjective boundaries presents a challenge, since current technologies are only beginning to be able to monitor people's responses on an ongoing basis. Although we can tag data collected with their collection date, these relatively infrequent "snapshots" are likely missing many important dynamic phenomena. Future technologies may soon enable place information to be gathered at regular and increasingly frequent intervals. No matter what technology is used to collect data, all studies must be prefaced with the caveat that they were collected during a particular period of time, and that current conditions may have changed significantly.

Subjective boundaries have much in common with fuzzy, closed natural boundaries. Natural boundaries occur when there is a discernable change in an ecosystem or the underlying physical geography. Examples of these boundaries include the shorelines of lakes and tidal zones and the boundaries between closed physiographic regions. In these cases, we have naturally occurring boundaries that may have a width ranging from a few meters (the difference in the location of a river's edge between high and low flows) to perhaps 100 km (62 mi.) (the width of the foothills that separate an isolated mountain range from the surrounding plains). The fuzzy nature of subjective boundaries is a reflection of their ecological nature as the interaction of many different factors.

1.6 Place Attachment

The concept of "place attachment" is defined as "a bond between people and their environment… based on cognition and affect" (Stedman, 2002, p. 563). There has been a great deal of research related to place attachment since the late 1970s. In 1992, Altman and Low co-edited *Place Attachment*, a seminal work describing then-current research. Later, Lewicka (2011) described a number of phases in the development of place attachment theory:

- Human geographers developed concepts of "sense of place" (1974-1980);
- Definitions of place attachment (1981-1985); and
- Development of theories of place attachment (1992-present)

Brunckhorst and Reeve (2006) also mention

- Empirical testing and refinement of theories of place attachment (1996-2003)

To this, we would add a new phase based on recently published papers (e.g. Brown, 2005; Gunderson & Watson, 2007):

- Development of methodologies for GIS-based analysis of place (2005-present).

Place attachment offers planners a framework by which public perception can be quantified. If place attachment to an area is high, we can select the area for preservation; where it is low, we can consider ways to improve the area. The higher the level of place attachment, the more likely planners are to face public opposition to any proposed changes.

Eisenhauer, Krannich and Blahna (2000) demonstrated that important places are non-substitutable. If, through an act of commission or omission, an important place is inadvertently destroyed, then it cannot be replaced. In a sense, this work confirms Tuan's statement that "What begins as undifferentiated space becomes place as we get to know it better and endow it with value" (Tuan, 1977, p. 6). In essence, the destruction of a place has similarities to the clear-cutting of an old-growth forest. Just as the clock of ecological succession is rolled back by a clear-cut, the development of place begins anew when a place is erased. Although archaeologists may later attempt to resurrect some of the "sense of place" of ancient, buried settlements or cities, their discoveries are a poor substitute for the richness that can be found in an extant place. A recognition that places can be destroyed more easily than they can be created can be seen in the work of Augé (1992), leading concerned citizens to engage in "place-protective action" (Stedman, 2002, Devine-Wright, 2009).

Place attachment was first identified as an important attribute for natural resource management by Brown (2005). In that study, Brown pointed out that:

> Land managers ultimately require that special places, defined as places where people have some form of place attachment or identification, be spatially identified, along with the reasons for their importance, to engage in suitability or trade-off analyses. An operational bridge is needed to connect special place locations (geography of place) with their underlying perceptual rationale (psychology of place) for ecological planning and resource management purposes (Brown, 2005, p. 19).

The concept of place attachment has been used in a number of operational studies related to the use of wilderness areas. These include the use of wilderness by recreational homeowners (Kaltenborn, 1997; Stedman, 2002; Stedman, 2003), reactions of rural homeowners to a proposed hydroelectric project (Vorkinn & Riese, 2001), landscape preferences (Kaltenborn & Bjerke, 2002), landscape values (Brown & Raymond, 2007), resource governance regions (Brunckhorst & Reeve, 2006), reactions to projects in natural forests (Gunderson & Watson, 2007), and the attachment of wilderness users to recreational areas (Lowery & Morse, 2012; Williams, Patterson, Roggenbuck & Watson, 1992). Some of these studies have a planning aspect to them, which leads us to ask why the concept has not been operationalized in standard planning procedures. As Norton and Hannon (1998) state:

> Despite the increasing interest of environmentalists and planners in the idea of place, however, little has been done so far to operationalize this intriguing but elusive concept, and it has been given little emphasis in actual analyses of environmental values. As a result, important applications have not occurred because of the inability of practitioners of multiple disciplines to settle upon a concept that is operational and sufficiently transdisciplinary to unify insights from the disciplines, all of which address the subject of place from different perspectives and with differing emphases (p. 124).

Brown, Raymond and Corcoran (2014) built upon previous studies to create "a spatially explicit method for identifying place attachment" (p. 42). Although their method of operationalization is different from the one discussed in this chapter, the importance of tying concepts of place attachment to the real world cannot be underestimated. In their words, "Arguably, until place attachment can be meaningfully rendered on a map, it will not be influential for land use planning and decision support" (p. 51).

Places are invested with a strong sense of meaning by those who use them. Brown and Raymond (2007) found that wilderness, aesthetic and spiritual values were strong predictors of ***place identity*** and ***place dependence***, the major components of place attachment. Williams *et al.* (2013) state, "Sometimes sense of place seems to refer simply to images, beliefs, ideas or cognitions linked to a geographic location. Designers, literary writers, and others may articulate a somewhat different perspective, referring to evoked feelings and suggestions that certain places exude positive feelings, harmony, or character" (pp. 5-6). Jackson (1994) spoke of *genius loci*, a Latin term for the "guardian divinity" or "supernatural spirit" of a place. While the survey questionnaires were being administered, a number of study participants spoke of the "spirit of the park" and described a peaceful presence that they felt near the lakes.

Williams (2014) cites Gieryn (2000), who states "Places are not only materially carved out of space but interpreted, narrated, understood, felt, and imagined -- their meanings pliable in the hands of different people or cultures, malleable over time, and inevitably contested" (Williams, 2014, p. 76). Different proposals cause people to reflect on their values and the places that they consider to be important, leading to disagreements over the ultimate disposition of a place: "Proposals for new land uses... communicate a sense of place defined by an outsider... and threaten the local sense of place, thus representing the power of the outsider over the local" (Williams & Stewart, 1998, as cited in Williams *et al.*, 2013, p. 12). When the meaning or future of a place is contested, it is difficult to reason with people who have strong place attachment. It is maybe even more difficult when they believe that a metaphysical entity is supporting them in their cause. This might help to explain the following observation by Norton and Hannon: "Nontransferrable, place-relative values have measurable behavioral consequences. For example, we predict that communities with a large stock of these values are more likely to continue to contest land use decisions, incurring measurable costs, even after they have been offered compensation" (Norton & Hannon, 1988, p. 134).

Work on what geographers call "a sense of place" and what others have called "place attachment" has slowly led to a better understanding of what motivates people to resist or be an agent of change. The breakdown of place attachment into place dependence and place identity components by Williams and Vaske (2003) provides a starting point by which field measurements can be combined to obtain a measure of place attachment.

1.7 Visualizing Place Attachment

Geography is the study of spatial patterns and associations between spatially distributed objects. James (1954, cited in Relph, 1976) states that “Geography is concerned with the association of things that give character to particular places.” Geographers want to understand a "sense of place," which is frequently referred to in other disciplines as place attachment (Williams & Vaske, 2003). Place attachment refers to the strong bonds that people develop for particular places.

The main tool used by geographers for understanding spatial associations is the map, whether it is paper or digital. Using geographic information systems (GIS), geographers are able to handle enormous amounts of map data, and process it in ways that have never before been possible. One way that GIS can be used is to map place with great accuracy and unprecedented detail, making many facets of place visible and available for analysis.

Unfortunately, although places are considered important, it has been difficult to establish the boundaries of place using any method other than arbitrarily drawing lines on a map. If we remove *fiat* boundaries from the map (Smith, 1995) and ask people to draw the outline of a place on a map, no two answers will be the same. Doreen Massey describes the fundamental problem of mapping place, when she states:

> Geographers have long been exercised by the problem of defining regions, and this question of 'definition' has almost always been reduced to the issue of drawing lines around a place. I remember some of my most painful times as a geographer have

> been spent unwillingly struggling to think how one could draw a boundary around somewhere like the 'east midlands' (Massey, 1997, p. 320).

The use of fuzzy boundaries (See Appendix B) solves this problem by allowing places to merge and overlap, a solution that is compatible with ecological transitions (ecotones) and First Nations peoples' concepts of land use (Rossiter & Wood, 2005). In this chapter, we present a new approach to mapping place that makes use of fuzzy boundaries, making places amenable to visual comparison and analysis, while enabling us to establish place-based boundaries, so that the geography of place studies can be advanced. Visualization can reveal the value of places, turning them from abstract concepts into objects that can be understood and worked with. Cacciapaglia, Yung & Patterson (2012) point out that "Maps can visually represent public views, enhancing dialogue by demonstrating how agreement varies across a landscape" (p. 454). The same can be applied to computer visualizations, which can be represented as colored maps or three-dimensional views. The visualization of place benefits not only geographers, but will also help sociologists, psychologists and planners in their research and professional activities.

1.8 Some Approaches to Studying Place

Ever since the first maps were created, the goal of mapping has always been to characterize place in some form. The study of place has been an important area of research for geographers since discipline separated from natural philosophy in the 19th century. Indeed, Alexander von Humboldt, one of the last natural philosophers, is also regarded as one of the founders of biogeography. His studies of South America can be considered the first descriptive studies of place, as he described former Incan cities and explored the interior of the continent.

During the last 60 years, geographers have progressively refined their understanding of place, much of that through studies of "mental maps," the physical form of what psychologists term "cognitive maps." Taking the knowledge and experience of place in a person's memory and making it tangible has been a specific goal of geographers for many decades. The effort to understand how place works from a theoretical viewpoint has been complemented by empirical studies that can shed light on actual human behavior, and can be used to help theorists develop new hypotheses of how places work.

The seminal work in this area was that of Kevin Lynch, who wrote *The Image of the City* in 1960, based on research that he performed with a group of graduate students in several American cities. Since then, many empirical studies have been completed, a few of which are described below. Lynch's research was conducted in Boston, Jersey City and Los Angeles, where a small number of study participants in each city were asked to describe their neighborhoods during extensive, 1½-hour long interviews that included a walk-through of the neighborhood. Lynch's work is admirable for its depth, but the amount of effort required was gargantuan: "The small [survey] size was made necessary by the broad type of inquiry that was made and by the lengthy time required for the elephantine and experimental technique of analysis" (Lynch, 1960, p. 152). Further studies, particularly those of Klein (1967), attempted to streamline the complicated approach used by Lynch, but did so by reducing the complexity of the analysis and removing many of the nuances that Lynch was able to capture (Klein, 1967, as cited in Saarinen, 1969, p. 15).

One way to avoid the distortions in sketch mapping resulting from differences in artistic ability is to look for alternative methods for understanding cognitive maps that bypass the need for sketch maps. Gould and White (1992) were able to create an *information surface* that describes an individual's spatial understanding. Because they made use of the actual (projected) locations of cities, Gould and White were able to avoid the distortions that appear in the sketch mapping process. From this, they were able to demonstrate how spatial understanding grows as a child learns, and that an information surface exhibits a logarithmic decay as one moves away from the point of origin. A related work, Strzalecki (1978), examined the emotional involvement of people with cities, and found both logarithmic and linear relationships for cities at ***Euclidean distances*** of less than 5000 km (3100 mi.). At distances greater than 5000 km (3100 mi.), a parabolic function was found. These studies demonstrate that planimetric maps based on Euclidean coordinates can offer insights that may be missing from sketch maps, which are non-Euclidean. Emotional attachment to place can be modelled as a logarithmic decay surface that extends outwards 5000 km (3100 mi.) from that place, and therefore never dissipates entirely.

More modern techniques, such as those employed by Reades, Calabrese & Ratti (2009) performed data mining on anonymized cell phone records, which required much less labor, but did so at the cost of abstracting the study of place to its most fundamental essence. From this study, the authors showed where people congregate at different times of the day in Rome, allowing for the discovery of several previously unknown places. For example, Reades *et al.* discovered locations where motorists pulled over to phone home prior to driving onto the beltway that surrounds the city.[3]

[3] Discovering new places that have been created in a city that is thousands of years old underscores how places are dynamic. New technologies can create places where none previously existed. The high temporal resolution of the data used by Reades *et al.* (2009), shows us that places can be ephemeral, and may only exist for a few hours per day on certain days of the week.

Other data mining techniques used by Bertrand *et al.* (2013) clustered geo-tagged "tweets" from the Twitter social media system to assess the mood of residents of New York City. This technique was used to generate an overall map showing sentiment, and identified some unhappy residents in highly localized areas near former toxic waste dumps. All that was learned from these studies was where and when these places existed, and in the case of Bertrand *et al.*, there was a measure of local sentiment. Bailón (2013, as cited in Kitchen, 2014, p. 144) stated "…mapping the spatial distribution of positive emotions, or the frequency with which certain words are mentioned in online communications, does not tell us much about the correspondence of those patterns with the social dynamics that underlie and generate them…." While important and groundbreaking, both of these data mining studies fell short of the detailed understanding of places that Lynch was able to acquire 50 years previously.

GIS offers an opportunity to handle the complexities that stymied Lynch, but only if it is used in an effective manner. Reducing the richness of place to a series of lines, points or polygons in a standard GIS representation throws away an enormous amount of information. McCall (2003) pointed out that this was one of the limitations of GIS technology: "To elicit and handle local perceptions and conceptualisations of space and spatial values: This would involve capturing and translating spatial concepts… into mappable outputs…" (p. 555).

Beginning in 2005 with the work of Greg Brown, a number of researchers have pursued an empirical, GIS-based research agenda. These techniques have been able to overcome some of the limitations mentioned by McCall, and are more compatible with the work pioneered by Lynch. Using progressively more sophisticated techniques, including participatory methods, this research agenda is progressing towards a practical form of Lynch's analysis. Many of the techniques that I describe in Chapter 3 fall within this research agenda.

1.9 Previous Approaches to Mapping Place

Through empirical and theoretical work, geographers have been refining the concept of place over the past six decades. A great deal of early work focused on understanding how people conceptualized their environment, as revealed by the construction of "mental maps" – sketch maps of an area that show people's perceptions of where objects and place boundaries are located. Typically, people who construct mental maps will exaggerate the size and reduce the distance to locations that are important or well known, whereas they will decrease the size (or entirely ignore) unimportant or poorly known areas (Lynch, 1960; Gould & White, 1992). The variable scale of mental maps makes it difficult to reconcile mapped features with those found on maps that have a uniform scale (Golledge, 1978).

Early empirical work, particularly the work of Lynch (1960), as discussed in Chapter 1, has been built upon by modern researchers using GIS, including Brown (2005), Brown & Raymond (2007), Brown, Raymond and Corcoran (2014), Brown and Reed (2012), Brown and Weber (2011), Carver, Watson, Waters, Matt, Gunderson and Davis (2009), Gunderson and Watson (2007) and Lowery and Morse (2012). The use of GIS has enabled these researchers to transcend many of the problems that Lynch had when collecting and processing data before computers and appropriate software were commonly available.

While the methods developed during the past decade are innovative and have advanced our understanding of place, there are several issues with these related to data collection, the representation of features, and interpolation procedures. Such computer-based approaches, even in an era of ubiquitous computing, still have issues of accessibility for the disadvantaged.

With the introduction of GIS, there has been a gradual shift from traditional (paper-based) collection techniques to digital collection techniques. Brown (2005) initially had participants place adhesive dots onto paper maps provided as part of mail-in surveys. This procedure located features with moderate precision and accuracy, but represented the areas between these poorly.

Gunderson and Watson (2007) and Lowery and Morse (2012) approached the problem of collecting data from study participants by having them draw crisp polygon boundaries onto paper maps during participatory mapping sessions, and then digitizing and overlaying these boundaries to create discrete fuzzy regions.

Newer, digital data collection techniques, such as those employed by Brown and Raymond (2007) and Brown, Raymond, and Corcoran (2014) are being employed to map place attachment. Study participants place dot symbols directly onto a map displayed on a computer screen. The values associated with the dots may represent landscape values (Brown & Raymond, 2007), experience, impact and other variables for study participants (Brown & Weber, 2011), social landscape metrics (Brown & Reed, 2012), or variables related to place attachment (Brown *et al.*, 2014).

Carver *et al.* (2009) developed a method that, like the latter methods adopted by Brown *et al.*, uses digital input. However, in this case, the software developed utilizes a "spray paint" metaphor on a digital map. The study participant can "spray" areas of high importance for a long period, and apply little or no "paint" to areas of low importance; other buttons allow the person to spray the entire study area or to erase areas. This technique is innovative because it allows for the generation of a fuzzy surface directly. Although this method is precise, it lacks accuracy because it is difficult for the user to indicate the exact location and degree of place attachment.

These computer-based techniques allow data to be processed as soon as a "submit" button is pressed. They also make it possible to collect data from websites; Carver *et al.*, (2009) point out that collecting data on a website allows for fully automated data collection at all hours by participants who have access to the internet.

All of the studies to date examine a fixed study area at a fixed scale. This encourages the use of scale-based optimizations, such as the choice of a single geometric primitive for a study (points at small scales and polygons at large scales). A general solution, useable at all map scales, should use not only points, but also lines and polygons.

The methods that have evolved from Brown (2005) assume that everything can be represented as a point. While this is a valid assumption at small map scales, the method does not translate well to large map scales, in which features are increasingly likely to be represented as polygons (Lowery & Morse, 2012). The methods employed by Gunderson and Watson (2007) and Lowery and Morse (2012) allow participants to show places of interest as polygons, which is most appropriate for medium and large map scales. At small map scales, the polygons may be very small, and degenerate into the points used by Brown *et al.* (2014). In all of these approaches, there is no easy way to identify an important linear object on a map, such as a river. It would be necessary in this case to draw an area around a line on the map, which is tedious.

The methods described attempt to deal with the difficulties of data entry into a computer; in many cases, the problem is easier to fix if it is simplified for applications at particular scales of study. However, such optimizations limit the scope under which the solutions can be applied. A broader approach can help to develop tools that are usable for a broad range of activities at different scales.

While using point symbols is convenient for the participant at particular map scales, the authors must consider how to create a continuous surface from point symbols; Brown and Weber (2011) and Brown *et al.* (2014) make use of a kernel density function to interpolate the values between points. There is nothing inherently wrong with this approach, however it should be noted that this is one of many possible interpolation methods, and there is no underlying theory that indicates that this particular method is superior its alternatives, such as inverse distance weighting, surface generation using splines, trend surface analysis or kriging.

It is important to consider the economic status and level of computer literacy among study participants. Many of the "native digital" techniques require that participants own a computer and/or have access to the internet. While this is undoubtedly economical and convenient for the researcher, it may limit who is able to take the survey.

Having a participant perform a mapping task relies on a level of map literacy that not all study participants may share. Mapped features may be placed with very low accuracy, or the participants may identify the wrong place entirely. Brown (2005), for example, noted some unexpected results when markers were placed onto "empty" spaces on the map. This leads to the question of what percentage of markers were simply placed in the wrong location by participants with poor map literacy. The Carver *et al.* (2009) "spray paint" method also requires that the study participant shades areas accurately; the user interface makes it difficult to ensure that the "peaks" in the fuzzy surface coincide with the location of the areas that participants find important.

For less computer-literate participants, computer-based approaches may limit their participation. The use of a computer mouse or graphics tablet to draw lines on a computer screen requires excellent eye-hand coordination, and may be another explanation for some poorly placed features. Data entry applications need to be designed to be easy and efficient to use, so that they can be mastered in relatively little time.

In the Gunderson and Watson (2007) and Lowery and Morse (2014) papers, each participant was responsible for drawing the boundary of the area being described, so the boundaries were unlikely to be properly aligned on the map. In this sense, their approach suffered from many of the same issues found by Gould and White (1992), in which different study participants provided significantly different descriptions of the same area because of their drawing skills, rather than because of significant differences of opinion.

1.10 Research Questions

The general goal of the *PlaceInGIS* project is to make a person's understanding of place visible, comparable and amenable to analysis. To accomplish this goal, we needed to address five general research questions.

The first of these is whether it is possible to take emotional concepts and quantify them. Can we question survey participants about their emotions, structure these and convert them to numerical values?

The second question is how do we combine quantified emotional concepts (place identity) with numerical values representing place dependence. Is it possible to combine different epistemological concepts, and if so are they weighted equally or differently?

Question number three is how to tie concepts of place attachment to the real world. Do we ask about people's place attachment to overall pre-defined areas or individual mappable objects in the study area? Do we ask them to draw the outlines of important areas, place dots at the center or over top of important places (Brown, 2005) or do we ask them to "spray paint" areas of importance, applying larger amounts of paint to more important areas (Carver et al., 2009)?

The fourth question is how to combine information for specific features into an overall picture of place attachment, if we do not ask for a single value for an area. A related question is how to interpolate between individual mapped objects, if gaps exist between them. What method of interpolation is correct?

Question five is how to combine and compare overall representations of a place when dealing with multiple study participants. How do we analyze the results to understand the differences and similarities between representations of the place understanding of different participants or groups of participants?

1.11 General Approach

To address these questions, the Place Analysis System (PAS) was developed. The PAS is an add-on to ***ArcGIS*** 10.3.1 (ESRI, 2017a), which, for the first time, enables the visualization of places as they are described during the administration of a short 10-15 minute questionnaire. The system creates a ***georeferenced*** three-dimensional fuzzy surface that represents place attachment, and communicates where areas of high and low place attachment can be found. The approach taken gives participants the ability to express their feelings and understanding of an area, which, until now, often came across as vague "hunches" even though these may have been built up from years of intimate involvement with a particular place.

Because we make use of fuzzy place attachment surfaces, it is possible to represent the strength of place attachment at locations being studied, as well as at adjoining locations. Since we can work with data for groups of people, we can compare how different groups view the same areas, or we can compare the strength of place attachment for neighboring areas, and calculate optimal boundaries between them (Leung, 1987). Analyses like these hold the potential for the development of a completely new form of geographical analysis, substituting precise analytical methods for older, descriptive studies of place.

When discussing the involvement of ordinary citizens with GIS, two terms have been created. One of these is "public participation GIS" (PPGIS) and the other is "participatory GIS" (PGIS). Elwood (2006) contrasts PPGIS with PGIS by examining the access, power relations and knowledge embedded in each type of system. Despite the unfortunate similarity between these two commonly used acronyms – PPGIS and PGIS – the two approaches have significant differences. To avoid confusion, I will avoid using these acronyms in the rest of the discussion. Whereas Public Participation GIS involves citizen control and access to GIS and diverse sources of knowledge, Participatory GIS assumes that GIS technicians are still in control, and that there are fewer options for input from the public as a result. Whereas Public Participation GIS is revolutionary, Participatory GIS is evolutionary.

Elwood discusses how one of the main differences between the two is access to technology. With a Public Participation GIS, community organizations may opt for "appropriate technology" rather than the latest innovations in GIS, because a limited set of GIS functionality is better than no functionality at all. Focusing on a core set of basic functions may be easier to adopt, particularly if there is limited technical capacity in the community group (Elwood, 2006). The Public Participation GIS approach may be very effective from a political point of view as community groups struggle to put forth their perspective(s) during debates with governmental agencies, but it may not produce well-reasoned answers to complex issues.

While Public Participation GIS is arguably driven by grassroots organizations, the same cannot be said for Participatory GIS. Elwood (2006) discusses the three main types of changes present in a Participatory GIS, and these include:

> …altering participatory decision making processes to enable more equitable access to GIS and digital spatial data; developing new representational strategies to diversify the forms of spatial knowledge that can be included in a GIS; and re-designing GIS software and databases to alter the way in which they represent and analyze spatial data in digital form (p. 695-696).

By this definition, the Place Analysis System is a Participatory GIS, but the lack of ongoing public involvement and direction disqualify it from being considered as a Public Participation GIS.

Although Elwood (2006) is somewhat dismissive of the Participatory GIS approach, she does acknowledge that this approach can be useful for the development of new methods of obtaining and processing public input. Elwood's argument fails to recognize that with a Participatory GIS, there can be an effective symbiosis when GIS technicians are able to work closely with patient and dedicated community members.

Such a symbiosis lies at the core of the PAS – letting the experts use the technology effectively and letting community members provide as much information as they can in a form that is not restricted by simplistic assumptions forced upon them because of the need to simplify the data for standard GIS analysis. At its heart, the PAS embraces a philosophy of unrestricted input; the system is designed to take any form of spoken, written, sketched or digital input, allows for an unlimited number of features to be discussed. Eventually, the system will merge quantitative and qualitative data collection methods. The role of the PAS is to act as a repository for raw data about place and to act as a platform for processing data and performing analysis, leading to new ways of understanding places.

Where the PAS adheres to traditional GIS analysis is in the representation and location of source data features on the ground. Professionally collected spatial data, either from existing datasets or from GPS measurements, are used to map all features that are mentioned by citizen participants. The reason for this is to allow the findings made with the PAS to remain compatible with other GIS. If the goal of citizen involvement in GIS is to communicate multiple perspectives effectively to governmental organizations, then, if nothing else, this must be done spatially. Sack (1997) points to the power of maps in promoting a neutral viewpoint:

> To help remove ourselves from our partial experiences and examine them from a more distant view, geography has developed a system of mapping. This system is a grid, or space, with x- and y-axes that can conform to degrees of longitude and latitude. Within this spatial system, any of the elements of the earth's surface can be symbolically located.... This view from above is not mine or anyone else's personal perspective; it is an impersonal view that can be employed by all of us (Sack, 1997, p. 177).

Community and governmental organizations have different knowledge bases, different ontologies and epistemologies, such that they may not even be able to communicate effectively. However, if both groups can agree that there is a problem at a particular location, and maybe even exchange layers of compatible spatial data, then we are much closer to building a common understanding and resolving disputes.

1.12 Overview of Dissertation

In this dissertation, I will present a method for using GIS to characterize places, which offers significant advantages over other methods that have been developed. By using previously geolocated features, mapping ***place attachment*** using a logarithmic decay surface and combining the ***feature surfaces*** into ***place attachment surfaces*** (for individuals) and ***summed surfaces*** (for groups), this new method may provide insights that are not possible with previously described methods.

This dissertation builds a case for, and provides examples of how place can be modeled in GIS. Chapter 2 is a discussion of the geography and history of the study area. In Chapter 3, I explore the data and methods that have been developed, and examine the rationale for the design decisions that were made for the PAS. Chapter 4 then presents the place attachment surfaces created using the PAS and show how they can be visualized and analyzed individually. Chapter 5 shows that the findings are consistent with the inputs provided by the study participants, giving evidence that the PAS works as planned. The next chapter discusses the first tool to analyze summed surfaces from multiple participants. This demonstrates how the PAS can be used in planning studies, and how it can be employed for prescriptive modeling by recommending a limited number of options for the planner's consideration. Chapter 7 demonstrates a second tool, which can be used to examine how the PAS can be used to determine the core and periphery of a study area. Chapter 8 discusses some of the details and issues that arise from the PAS. Finally, Chapter 9 looks at the changes that are required to make the PAS more effective, and considers follow-up studies that may be performed with current and upgraded PAS software and procedures.

Chapter 2: Study Area

Colliery Dam Park is a 27.96 ha (69.10 ac.) city park, located in Nanaimo, British Columbia, Canada, a city of 90,000 people located on Vancouver Island (Figure 2.1).

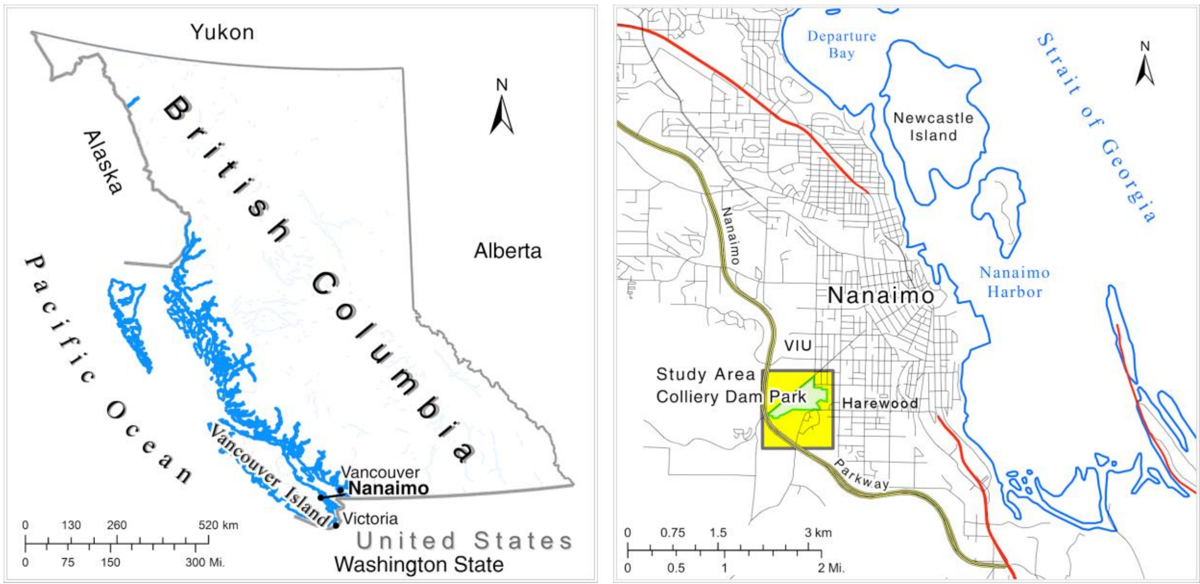

Figure 2.1. The study area and Colliery Dam Park in the context of British Columbia and Nanaimo.

A number of different places were considered for the study area, based on six criteria. These were:

1. The place must be safe to work in, particularly when few other people are around.
2. The place must be well known and well used.
3. The place should be easy and inexpensive to access (i.e. in Nanaimo or within a 1-hour drive).
4. The place must have a lot of pedestrian traffic to ensure that enough people can be surveyed.
5. The place must be easy to work in for many hours.
6. The place should benefit from this type of research.

Initial consideration was given to study locations as far away as Victoria, 111 km (69 mi.) south of Nanaimo, but the list was quickly shortlisted to six locations in and around Nanaimo, including:

- Maffeo-Sutton Park, a small, moderately developed urban park on the city waterfront featuring a lot of foot traffic;
- Rathtrevor Beach Provincial Park, a large wilderness Provincial Park 36 km (22 mi.) north of Nanaimo;
- Woodgrove Centre, Nanaimo's largest indoor mall (150 stores), located in North Nanaimo;
- Piper's Lagoon Park, a small semi-wilderness waterfront park in North Nanaimo;
- Neck Point Park, a large and popular semi-wilderness park in the north end of Nanaimo, which faces Piper's lagoon from the opposite side of Hammond Bay; and
- Colliery Dam Park, a semi-wilderness park in South Nanaimo

Maffeo-Sutton Park was ruled out because of the frequent use of the park for special events by the City, which would have precluded data collection on a frequent basis. Rathtrevor Provincial Park was ruled out because of its distance from Nanaimo. Woodgrove Centre, although indoors, presented issues with permissions and restrictions, particularly the hours of data collection that would be available in this private facility. Piper's Lagoon Park is quite small, features fairly limited foot traffic during much of the day, and is very exposed to high winds and ocean storms.

Neck Point and Colliery Dam Parks remained as the only serious contenders for the study, and were equal in many respects, but the unparalleled accessibility of Colliery Dam Park led to it being chosen as our final study location. The park is located near my home and lies only 300 m (328 yd.) south of Vancouver Island University, my employer.

The park offers four important advantages. First, since this was the first time that I had done research of this type, I was uncertain of the level of safety that would be required while conducting the survey. There was a possibility that the student research assistants I had available would be working alone, and it was certain that I would be working alone in the park during the data collection phase and possibly during the survey. For this reason, I chose an area that I was certain was safe, given that I had walked back and forth through the park every day on my way to and from work, with no incidents in six years.

Second, I knew that many local residents were proud of the park, however, it was not until we commenced the survey that it became apparent just how important the park was to local residents. There were residents who had lived in the area for decades and others who had deliberately moved into the area to be close to the park.

Third, the park was large enough to be interesting, yet small enough that park users could be surveyed *in-situ* with a team of two. This park has a long history, is quite dynamic and is now undergoing rapid change as Nanaimo expands around it. In 2010, the city completed a water main through the park, which included a bridge over the Chase River; later, a new covered reservoir for the Nanaimo water supply was started within the park boundary.

Fourth, and perhaps most important, the City of Nanaimo has a number of progressive policies that made this project relatively easy to conduct in a Nanaimo city park. No permission was required to use the park to survey residents, as this was a public space, open to all. Also, the city of Nanaimo has an open access policy for spatial data, so a great deal of high-quality data about park features including LiDAR elevation data, orthophotographs, and vector data were free to download from the City's website. Although much of these data were not required for the study, certain layers, in particular road centerlines and cadastral data containing the lot boundaries were invaluable.

2.1 Geography of Colliery Dam Park

Colliery Dam Park, a semi-wilderness park located in the South Nanaimo neighborhood of Harewood is bounded by residential areas to the east, undeveloped city-owned lands to the south and west, and the Nanaimo Military Camp to the north. The centerpieces of the park are two artificial lakes on the Chase River that are held back by the colliery dams, which were originally built to support coal-mining operations (Figure 2.2).

Figure 2.2. The lower lake at Colliery Dam Park, taken from the lower colliery dam (photo by author).

The park extends 1.17 km (0.73 mi.) E-W and 0.69 km (0.43 mi.) N-S, and has an area of 27.96 ha (69.10 ac.). If we include the city-owned lands that unofficially serve as part of the park, the N-S extent of the park increases to 1.10 km (0.68 mi.), with an area of 45.19 ha (111.68 ac.). Although small, the park has much in common with larger parks that have sections of semi-wilderness within them, such as Stanley Park in Vancouver, Central Park in New York, or Rock Creek Park in Washington, DC.

The park is centered on the valley of the Chase River, which is 11 km (7 mi.) long and drains an area of 25 km^2 (10 sq. mi.) (City of Nanaimo, n.d.). As the river falls from its headwaters to the Harewood plain, it drops roughly 57 m (187 ft.) over 1.3 km (0.8 mi.). The valley features a number of interesting caves and cliffs. The study area is dominated by large stands of mature second growth Douglas fir trees (*Pseudotsuga menziesii*) with smaller numbers of western red cedar (*Thuja plicata*) and isolated groves of bigleaf maple trees (*Acer macrophyllum*).

The park currently offers 1.7 km (1.1 mi.) of paved trails, 1.0 km (0.4 mi.) of all-weather trails and 8.3 km (5.2 mi.) of unpaved trails. It is well known for its large off-leash dog area, and is a popular place for swimming, socializing, fishing and having picnics (Figure 2.3).

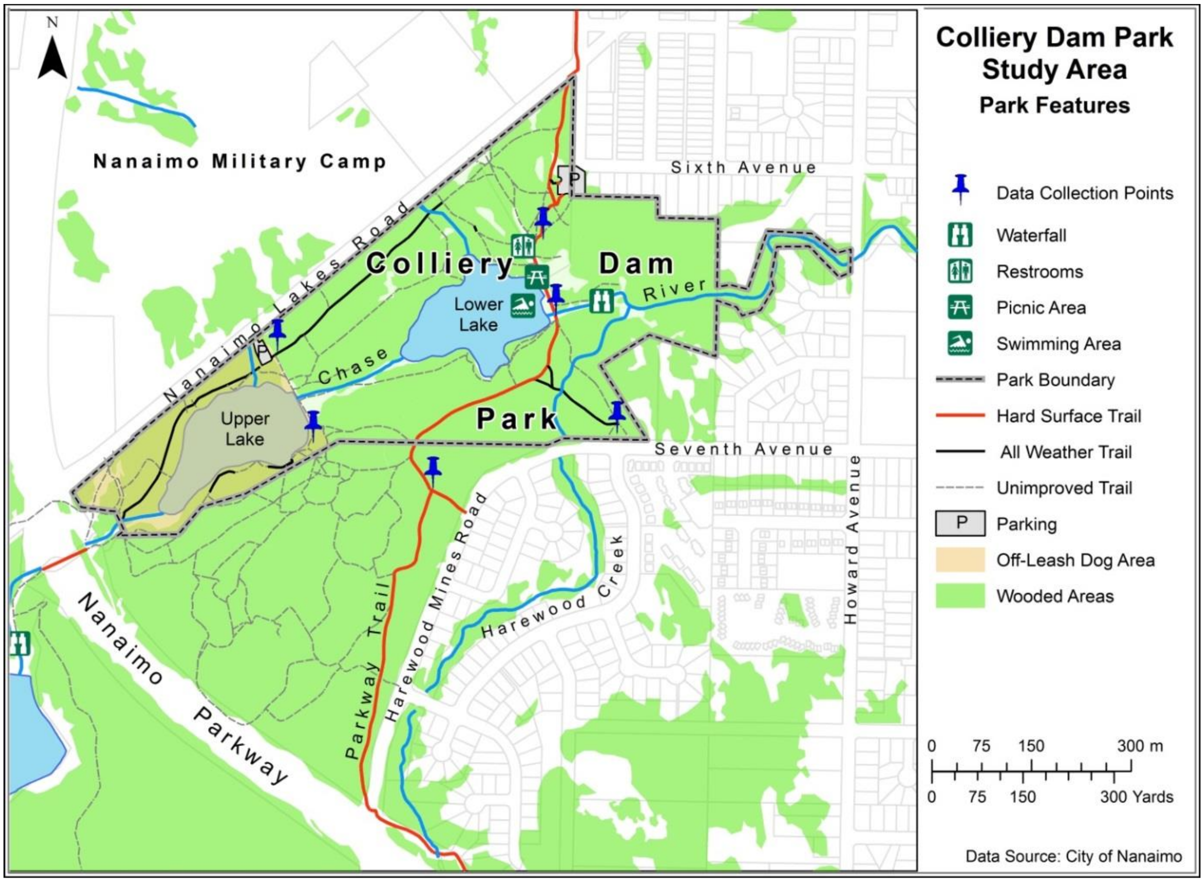

Figure 2.3. Features of Colliery Dam Park and the surrounding study area.

2.2 Recorded History of Nanaimo

Established in the 1850s as a coal-mining center, Nanaimo eventually became known for its forestry industry, and today has a diversified economy as a distribution, education and technology center. Humans have occupied this area for at least 10,000 years, as shown by the numerous petroglyphs found in the area. Direct evidence for Snuneymuxw occupation dates back 4000 years, based on archaeological studies of shell middens found in the area. In the mid-1800s, there were roughly 5000 Snuneymuxw people living in five villages in the Nanaimo region (Nanaimo and District Historical Society, 1983).

In 1851, a Snuneymuxw chief named Chewichikan informed the blacksmith at Fort Victoria that coal could be found near his home in Nanaimo. Chewichikan returned with a canoe laden with high-quality bituminous coal the following spring in exchange for repairs to his gun and a bottle of rum (Hudson's Bay Company, 2016). The Hudson's Bay Company (HBC) dispatched Joseph McKay to Nanaimo to take formal possession of the coal beds on August 24, 1852. The HBC subsequently dispatched the schooner *Cadboro* to Nanaimo, and construction was commenced on huts, a trading house and a coaling pier. Twenty-one experienced miners began mining almost immediately, and the *Cadboro* returned to Victoria laden with coal on September 10, 1852. The HBC then transported 75 people, composed of 23 families and 10 single men from Britain to Nanaimo aboard the *Princess Royal* (Norcross, 1979). After a six-month journey, these settlers arrived on November 27, 1854 (Nanaimo and District Historical Society, 1983).

Coal mining rapidly expanded and continued operating in Nanaimo for the next century; at least 16 major mines operated at various times. The last major mine closed in 1950, but small-scale mining continued until 1967. More than 45 million tonnes (50 million tons) of coal were extracted from Nanaimo and the communities that sprang up around it (Nanaimo and District Historical Society, 1983). One of these was Harewood, which, like many other mining towns close to Nanaimo, was eventually incorporated into the growing city.

2.3 Recorded History of Colliery Dam Park

The park contains evidence of First Nations use of the area, as well as extensive physical remnants of the City's mining history. At least sixteen culturally modified western red cedar trees (*Thuja plicata*) can be found in the park. These have had their bark removed from one side of the tree in a sustainable fashion by the Snuneymuxw people. The bark of the western red cedar was traditionally used for many purposes, including clothing and baskets. Although the evidence is of contemporary use to maintain cultural traditions, it suggests that the area may have served similar purposes historically. Some self-identified First Nations participants also described the location of a natural pool of water in the Chase River that has spiritual meaning.

The recorded history of the Colliery Dam Park area began less than five months after Nanaimo was colonized. Two ***First Nations*** men had been accused of murdering two European farmers near Victoria, and had fled northward. The first, named Sque-is, was captured at Cowichan Bay, near present day Duncan, but the second, Siam-a-sit reached Nanaimo. Fleeing his pursuers, Siam-a-sit travelled inland along a river, later named the Chase River after this event, before being captured and returned to Victoria (Harewood Centennial Committee, 1967).

Between its First Nations and colonial history, the area of Colliery Dam Park has had a rich history that has been recorded for over 160 years. During that time, the area has served various land and water-based functions. It was likely used as source of western red cedar bark (*Thuja plicata*) and was used for ritual bathing by the Snuneymuxw people. During the era of coal production, it was the location for a number of industrial and civil reservoirs, which supplied water for washing coal and for domestic use. It also served as the route for a rail spur line serving the Wakesiah mine, and as the location of a hospital. It was used by as a source of lumber at some point, as evidenced by the many large stumps in the park. During the Second World War, it served as a military training area, and more recently, it served as a city park and the route for a freeway.

At the peak of coal mining in Nanaimo, there was a need for large quantities of water to supply coal-washing operations on the Nanaimo waterfront. The Nanaimo city water supply, which was drawn from a reservoir on the Chase River, was unable to supply sufficient water for the washing of coal at the No. 1 mine (No. 1 Pit HBCo. in Figure 2.4). To obtain a reliable supply of water, the Western Fuel Company decided to build the Colliery Dams to create two additional reservoirs downstream from the city reservoir.

To construct the lower dam, a rail line was built as far as the Chase River (Figure 2.4). Heavy equipment was brought in by rail to deepen a natural basin in the river and to erect dams on top of two cataracts in the river. Construction of the lower dam was begun in 1910, and on May 1, 1911, a valve was closed to mark its completion. The water from this reservoir was carried to the waterfront in a 30 cm (12 in.) wooden pipeline (Harewood Centennial Committee, 1967).

In addition to the Colliery Dams and the foundation of the spur line, various other earthworks and the supports for a pipeline that once transported the city's water supply can be found in the park. The concrete foundations for the hospital, known as the "Pest House" are still visible. This was established in 1908 during a smallpox outbreak among a group of railway workers (Harewood Centennial Committee, 1967).

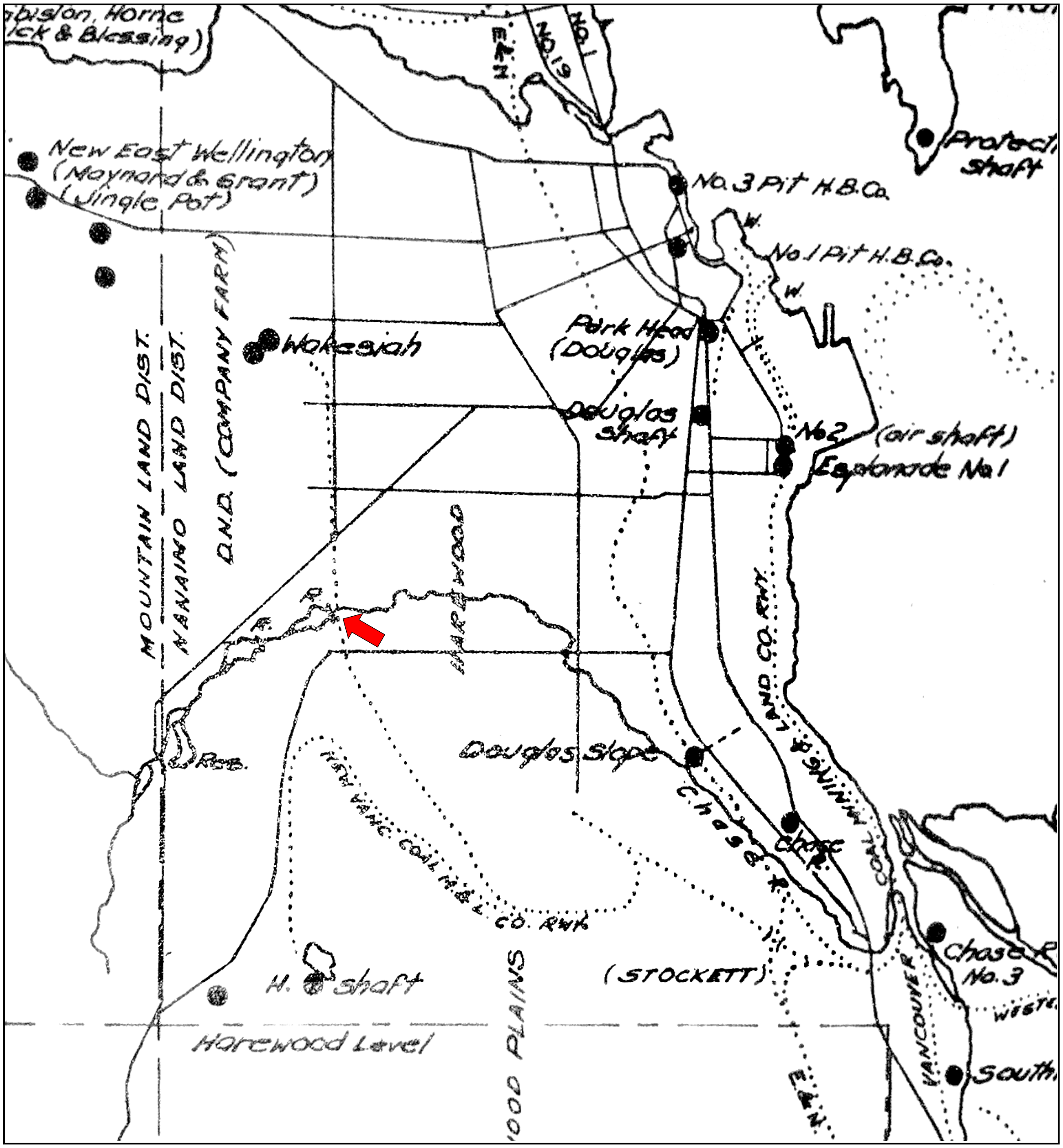

Figure 2.4. Portion of a map showing mining infrastructure around what is now Colliery Dam Park. The two reservoirs (marked R.) on the Chase River are now the lower and upper colliery lakes. Notice the mining railway spur line (dotted) running north south across the Lower Colliery Dam (arrow), which connected the Wakesiah Mine with the Esquimalt and Nanaimo (E&N) railway. (Leynard, 1982).

Colliery Dam Park is within easy walking distance of many Harewood residences, making the park a popular place for walking and swimming during the summer. The current area was designated for park use in 1954 (Leynard, 1982). In 1975, the City of Nanaimo acquired

Colliery Dam Park when it absorbed Harewood, which until then had been a separate community (Gorman, 2012).

2.4 Significance of the Place

The area's rich history and long tradition of recreational use have played a key role in forming the biographies of many local residents, as Allen Pred would have recognized. Because of this, there is a strong sense of place attachment to the park by local residents, both old and young; some of whose families have been visiting the park for generations.

The strong sense of place attachment among local residents is a great resource for scholars. The pride that people feel about "their" park is evident, and users of the park have been very eager to share their stories. During nearly a year of surveying park users, conducted in all seasons and weather conditions, we were able to obtain information about this place from 302 people and store it for current and future analyses. This data resource has already yielded insights into how people perceive place, and will continue to do so for many years as future analytical techniques are developed for the PAS.

2.5 Summary

Colliery Dam Park has a rich cultural and physical history. Unlike many places on the west coast of North America, Nanaimo was settled relatively early, and because of the importance of coal on the west coast, was established quickly as an outpost of European and Asian settlers. Peaceful contact with the Snuneymuxw people meant that their traditions were not lost, and today, Colliery Dam Park retains multiple histories, from both First Nations people and settlers. The colliery dams themselves are one of the last vestiges of a century of mining history. While there are many new residents of Nanaimo, some families have lived in the area for many generations. For them, Colliery Dam Park is a place for which they have a strong sense of place attachment. However, not only "old timers" love the park; many new residents become enchanted by the park and use it frequently or even move into the area to be close to it.

Chapter 3: Data and Methods

Places are incredibly complicated, as are the unique individual reactions that people have to them. Given such complexity, it is very difficult to describe places. Geographers have a better way of describing places than by using mere photographs, words or numbers. The map is a model of reality at a reduced scale. Geographic Information Systems (GIS) enable the storage of map information at different scales, and allow for other forms of description to be attached to the map. GIS is a powerful way to represent the complexity of place, and can store and analyze virtually unlimited amounts of information about places.

Using GIS, we can now model places accurately based on the concept of place attachment, which is the psychological importance that people attach to place. For the first time, we can show not only individual features, but we can also model how their place attachment changes over distance.

In this chapter, we outline the basics of modeling place attachment using GIS. We discuss the concepts and workings of the PAS, which permits the collection, storage, visualization and analysis of place information. The PAS allows accurate three-dimensional surfaces of place attachment to be constructed and viewed for the first time. These help to make the differences between individual and group views of place understandable in a way that is simply not possible using photographs, words or numbers. The surfaces lay the foundation for work done in subsequent chapters, where we examine some of the analyses that the PAS can perform, and examine how its results can be used to inform decision-making. The PAS supports detailed conversations about what is important in places. Such discussions can help people to build, manage and change places based on an understanding of place attachment.

3.1 General Overview of Approach

Calculating a feature surface for each line in the survey form provided by the participant is the first level of analysis in the PAS. The feature surfaces are combined and normalized to create a place attachment surface at the next level. A summed surface is created from the place attachment surfaces for groups of participants at the third level of analysis.

Study participants were first asked to describe as many features as they wished in Colliery Dam Park. For each feature, they were asked to provide three critical pieces of information:

1. the main emotion associated with the feature;
2. the importance that they assigned to the feature; and
3. the distance at which the emotion and importance fades to background levels.

Since each emotion in the Plutchik (1980) psychoevolutionary model of the emotions has a numerical affect value associated with it, we can combine it with the numerical importance value to come up with an overall place attachment value. The calculated place attachment value is found at the features described (points, lines, or polygons) and then decreases logarithmically as we move away from the feature. The function is scaled so that it reaches the background level at the distance specified by the participant. The background level is then maintained to the edge of the study area. For each feature, the resulting surface is called a ***feature surface*** (Figure 3.1).

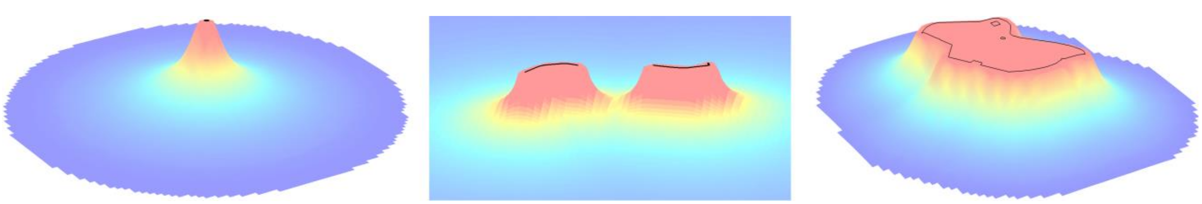

Figure 3.1. Feature surfaces for points, lines and areas, which are shown in black on top of the surfaces. A feature may be composed of multiple elements, such as the boardwalk in the center image, which has two parts, or may have holes, such as the polygon on the right. Note that the feature itself has a uniform place attachment value, and as you move away from it, the place attachment value decays with distance.

For each feature described by the participant, the resulting feature surfaces are combined together to create a ***place attachment surface***. The place attachment surface is a representation of how the participant understands and appreciates a place, based on the features that were described.

Place attachment surfaces are the foundation on which the Place Analysis System is built. A visual representation of how a participant perceives a place allows that perception to be communicated to others and analyzed, either by itself, or when combined with the place attachment surfaces of other people.

3.2 Advantages of Approach Used

The methods outlined in Section 1.9 are all different application-specific approaches to dealing with fuzzy data, which deliver results with varying degrees of success. Unfortunately, there is a tendency to do *what current technology enables*, rather than to consider *what is the best approach* and build technologies that support it. Until now, no general solution has addressed all of the following principles:

1. data should be collected close in space and time to where it was experienced;
2. the solution should not require study participants to be highly skilled or have access to computers;
3. the solution is ideally useable at all scales and thus supports points, lines, polygons or any combination of the three; and
4. interpolation methods require a theoretical background to justify the shape of the surface that they produce.

To address the first issue, the most important reason for collecting data in the study area (i.e., within the park) is that the features, emotions and understanding are fresh in the memory of participants. Although it is relatively easy to provide photographic reminders of places when surveys are conducted outside the park, such a method fails to recognize that memories are not a replacement for direct experience. Barrett and Barrett (2001) discuss the immediacy and accuracy of data collected in the field: "Experience sampling does not require retrieval or reconstruction of data from memory but rather involves access to and accurate reporting of information available to conscious awareness" (p. 176). Stedman (2002) cited Fazio (1989) who showed that emotions are a predictor of behavior when there is direct experience of the objects with which the emotions are associated.

If our objective is to quantify the degree of place identity for each park feature, then it is best to do this when they can be experienced directly with multiple senses. Sack (1997, p. 135) points out how these play a role in triggering memories: "Returning to a city where one was a child, the sights, sounds, and smells may trigger memories that might never otherwise be recollected." Eighteen participants specifically mentioned the visual aspects of the park, twenty-three mentioned the sounds or the quietness of the park and three participants mentioned the smell of the park in their comments. Tuan (1977) suggests that smell plays an important role in differentiating "place" from "placelessness," and this is supported by Willander and Larsson (2006), who have investigated the role of smell in evoking memories. Sight, sounds and smells all have a role to play in evoking a "sense of place," and to date the only way of integrating all three is for participants to complete the survey *in-situ*.

Although collecting data *in-situ* is somewhat more difficult than mail or internet-based sampling, some of the biases inherent in other methods are avoided. A random selection of park users resulted in a widespread set of social groups. Given that the park is located in Harewood, a lower income neighborhood of Nanaimo, the sampling likely included a number of people who might not have been reached by mail-in or internet surveys, which tend to sample from higher-income residents. On the other hand, because Nanaimo has a population of only 90,000, there may also be less social stratification at play than in larger cities. We surveyed one person who self-identified as homeless and another who self-identified as a millionaire. A large number of people choose to swim in the lake rather than pay to use the indoor aquatic facility only three blocks to the north. This may be partially explained by the limited income of some park users.

Despite its advantages, *in-situ* data collection is challenging. As Brown and Weber (2011, p. 2) point out, "It is difficult to engage many visitors in park planning when they are intent on enjoying limited leisure time. Further, parks are often large and dispersed... which makes intercepting park visitors difficult." Practical considerations limited our data collection sites to six points within the park. Unlike the other processing and analysis steps used in the PAS, *in-situ* data collection does not scale well with increases to the size of the study area or the population sampled. Having additional data collection points spread throughout the park would be better, but it is impractical with the current method, simply because many places in the park are rarely traveled. Ideally, it would be beneficial if participants could record data as they travel through the park, recording features on a paper form using a clipboard. Of course, the risk of losing surveys (and clipboards) goes up significantly with this approach.

Another approach might be to supplement paper questionnaires with a smartphone application to facilitate data collection. While a smartphone application could significantly improve the spatial, temporal and qualitative aspects of data collection, it use is limited to those who can afford smartphones. It is worth examining ways that this technology can be used in combination with less exclusive data collection techniques to provide a mixture of high-quality, high-resolution data as well as a breadth of collection that represents the entire community, both wealthy and otherwise.

To address the second issue, the skill level of participants, each object described by the study participant is matched with an existing mapped feature when the data are entered into the computer. Such a system of ***place-based nomenclature*** avoids the issue of requiring study participants to draw on a map. For most participants, it is far more natural to identify features using their preferred name, which provides for faster data collection, and facilitates the collection of additional qualitative information in the field. Carver *et al.* mention that:

> ...people usually talk about places they know, use or have visited either by name (i.e. place-based nomenclature) in more vague terms such as "the head of the valley beyond the lake" or "the woods out the back of my acreage" (Carver *et al.*, 2009, p. 437).

The study area is small enough that there is little ambiguity about the features being discussed, and in virtually all cases, this can be mitigated using face-to-face contact, gestures, pointing, and probes when the name of an object is uncertain. For larger areas, however, a catalog of features can be produced by the PAS, so that a combination of photographs and a textual description can be used to clarify ambiguities (Figure 3.2).

It is important that the catalog be used correctly if it is not to bias the study results. We are trying to determine what features the participant recalls in the park. The purpose of the catalog is *clarification*, not *identification*. If a participant is certain of the feature being described, but is unable to explain what feature he or she means, the researcher can find images in the catalog and ask whether these are what the participant means. The catalog

Figure 3.2. Three examples out of the 1322 entries in the catalog. Each record shows the feature catalog number, the official name of the feature, a description of the feature (frequently the same as the official name), the layer where the feature is located, the feature type and an image of the feature.

should never be provided to the participant as an aid to find features of interest, since this will bias the results of the research.

To solve the third issue, the method proposed in this dissertation offers a general solution for the creation of fuzzy surfaces from discrete, professionally mapped features. It can be employed at all map scales, as the results can be based on points, lines or polygons, enabling many existing vector data sets to be used. The existing mapped data are cataloged and organized before the start of the survey.

It is unfortunate that, in a world where high quality digital data are pervasive, we are not making better use of this resource. The main issue with re-using third party data is that they were likely collected for different purposes; we need to be cognizant that the data may be unusable for studies of place, and we might have to re-collect them for our purposes. Some features pertinent to the study will be missing, and these can either be collected using GPS receivers prior to, or at the time of data collection. At Colliery Dam Park, previously unmapped features needed to be collected only three times while surveying participants.

For the final issue, we could choose an interpolation technique from among the many different ones available, but the work of Ekman and Bratfisch (1965) and Dornič (1967) shows how the memory of places declines with distance. Just as people's understanding, memory and appreciation of places gradually decline over distance, the surfaces representing either the individual or collective understanding of place also decline over distance. Because the memories of places can be carried great distances (Ekman & Bratfisch, 1965), the place attachment and summed surfaces may extend worldwide. These surfaces may show areas of elevated values in foreign places where people have lived or visited frequently, separated by large expanses with low values across which people have travelled by high-speed transport, but have not experienced in depth. Based on this theory, we can create a more appropriate interpolation to represent the strength of people's memory of features where the actual values are unknown. We term this theoretically derived method of obtaining a raster ***theory-based interpolation***.

Feature surfaces can be constructed for each object based on the:

1. place attachment value;
2. the awareness distance provided by the participant; and
3. studies of how memories of objects decay with distance (Ekman & Bratfisch, 1965; Dornič, 1967; Massey, 1997).

These surfaces represent memories of place attachment to different features, and they may be treated as fuzzy sets.

3.3 Map Data Collection, Storage, and Retrieval

The method used in this study combines spatial accuracy, precisely located features, and a theory-based continuous decay surface. All features were mapped to within 3 m (10 ft.) of their exact location using the Universal Transverse Mercator (UTM) Zone 10 North projected coordinate system with the North American Datum of 1983 (NAD 83).

To obtain the required precision, we used a commercial-grade Trimble Pro XT GPS receiver to map most of the features ourselves. These data were supplemented with additional data collected from two sources: professionally mapped data from the City of Nanaimo or data digitized from a 10 cm resolution color ***orthophoto*** of features in the lakes.

Matching the features described by participants with professionally mapped features allowed us to avoid the inaccuracies in sketch maps made by members of the public. This is the first time that georegistered fuzzy surfaces have been generated to show place attachment, allowing the data to be combined with any other data in a GIS. Furthermore, the values at any point in the raster can be explained, given the features chosen by the participants, the place dependence and place identity values assigned to them, their location, the awareness distances and the decay surface.

The collection and cataloguing of spatial data prior to the commencement of surveying was very time consuming. Not all features that were mapped were mentioned by study participants, and conversely, a small number of features mentioned had not been mapped. In future, we will adopt elements of a Rapid Appraisal Methodology (Gunderson & Watson, 2007), particularly key informant surveys and snowball sampling (Lowery & Morse, 2012) during the pre-test phase of surveying. This will allow us to use the knowledge of experienced local residents while we build an appropriately sized inventory of features, prior to the commencement of the main data collection activities. Such an inventory will minimize the need to add new objects to the inventory, saving time for both the surveying staff and the participants.

Each point, line and polygon mapped was stored in one of 26 source layers, with names such as Infrastructure_Points, Infrastructure_Lines, Infrastructure_Areas or Recreation_Areas. Within these source layers, each object has a unique identifier number, which is listed in the catalog of features. Since a feature may consist of multiple points, lines or polygons, all objects of a particular type are extracted and placed together in a temporary layer to create each feature described by a participant.

Once the place attachment value has been calculated, each temporary layer has its Z value increased to its place attachment value, and then a decay surface is applied outward from the feature. This creates a feature surface (Figure 3.1, p. 56). Feature surfaces are floating-point rasters with a 2.5 m (8.2 ft.) resolution, and provide a compromise between providing enough detail and allowing efficient data processing. The PAS is able to create multiple feature surfaces for each study participant, based on individual objects (points, lines or areas), multiple objects or multiple objects of different types. When a feature is composed of mixed point, line and area objects, each type of object is processed separately in its own raster, given the awareness distance and place attachment value for the feature, and is then combined during the final step using the Fuzzy OR function. The result is the same as if the system had processed the points, lines and polygons together in the same layer.

3.4 Survey Procedure

Collecting information about place attachment in such an important place was relatively easy because of the enthusiasm of many park users. Care needed to be taken to design a survey that would collect both qualitative and quantitative data, and a system needed to be designed to store that data in an unaltered state, so that it could be used for current and future analyses of place attachment.

3.4.1 Collection Period and Frequency

Data were collected from Oct. 20, 2011 to Sept. 29, 2012 from six sampling locations located at well-traveled locations throughout the park (Figure 2.3, p. 48). The day of the week (including weekends) and time of collection (morning, afternoon, or evening) were rotated to maximize the chance of surveying people from different sub-populations of users. On average, a four-hour data collection session was scheduled every 4.4 days.

3.4.2 In-Situ Data Collection

In-situ data collection offers greatly enhanced communication between the researchers and study participants (Figure 3.3). Collecting data in the park allowed participants to point at features and use body language to communicate feature distance, direction, size and configuration. When written and verbal communications failed, participants were prompted to obtain clarification about the features being discussed. A more subtle benefit of this technique was that the level of engagement of the study participants could be assessed as they completed the survey questionnaire. On a mail-in or internet survey, such a level of assistance and supervision would not be available.

Figure 3.3. The author (left) and Student Researcher Chris Mueller (right), staff the portable office that was set up to administer the questionnaire in all weather conditions near the Upper Colliery Lake (photo by Brenda Maguire).

While mobility issues were not recorded in the survey, the extent of a participant's travels within the park was estimated by the location of the features that they mentioned. If a participant mentioned a feature, it was assumed that either they had a long-term memory of the object, or that they had recently visited the feature. Thus, the locations of features provided some indication of current or former travel routes through the study area. This demonstrates how *in-situ* data collection provides a better understanding of the movement of park users than do mail-in or internet surveys, which are unlikely to provide this level of detail about travel and park use.

3.4.3 Data Collection Method

Samples were primarily collected randomly; a simple method to do this was to roll a standard 6-sided die and then pick the *n*th passer-by that corresponded with the number on the die. At times of low traffic, convenience sampling was also employed; additionally, a significant number of park users volunteered to take the survey. The sampling method employed was recorded to ensure that if any differences were found in the results, they could be disaggregated by method of collection.

Not all responses by participants were analyzed. In cases where the participants demonstrated that they did not understand the nature of the questions being asked, discussed features that could not be mapped practically (e.g. the birds of the park), responded to the survey but provided no features to be mapped, or provided missing or impossible demographic information, their submissions were removed from the pool of valid responses. Out of 302 responses, 63 were rejected, leaving 239 responses for analysis. Table 3.1 details the number of participants by sampling and rejection category.

	Randomly Sampled	**Volunteered**	**Convenience Sampled**	**Total**
Not Rejected	142 (47.0%)	85 (28.1%)	12 (4.0%)	239 (79.1%)
Rejected	32 (10.6%)	26 (8.6%)	5 (1.7%)	63 (20.9%)
Total	174 (57.6%)	111 (36.8%)	17 (5.6%)	302 (100.0%)

Table 3.1. Numbers of participants by sampling method and rejection status.

The Kruskal-Wallis H test was used on the non-rejected responses to evaluate whether the three different sampling methods yielded similar place attachment values. Examination of the box plots produced showed that the distributions of the scores were similar, which was confirmed by the H values: $H(2) = 3.091$, $p = .213$, where 2 represents the degrees of freedom. Based on these findings, we are confident that all three sampling methods can be combined together to create an overall composite view of place attachment in Colliery Dam Park.

3.4.4 Data Collection Form

Participants were provided with instructions on what was required, and then were asked to fill out a consent form and a paper questionnaire describing the features in the park that they felt were most important (Figure 3.4). Each questionnaire form was pre-labeled with a 9-digit random participant number so that the responses could be tracked, but also kept anonymous.

Each study participant was asked to describe his or her perceptions of the overall park and a minimum of one additional feature of importance within the study area (Figure 3.4). For each feature, both qualitative and quantitative information was solicited from study participants.

3.4.5 Entering Information into the Data Collection form

In the data collection form, for each feature described, the participant is first asked to enter a feature name. This is a descriptive name, using the participant's own words, which explains what they are trying to show.

Participants were next asked to provide the main emotion that they associated with that feature. To help participants choose an appropriate emotion, they were provided with a reference card (Figure 3.5), which suggested 53 possible emotional words in addition to "no emotion." Thirty-two of the emotions listed on the reference card were shown on Plutchik's

Questionnaire PlaceInGIS.com Participant 362199345

To be Completed by Participant

In this section, we want to know what you think and feel about particular features in the park. We want to know how important each feature is, why the feature is important to you, how far away you notice the feature. In addition, we would like to know how you feel about the park overall. An additional form is available if you would like to describe more than seven features.

Feature Name	Main Emotion (see card)	Reason for Importance / Comments (optional)	Importance (1 - 7, see below)	Awareness Distance (metres or V, see card)
Colliery Dam Park (overall)		SWIM FOR HUMANS ALSO	6	50M
UPPER LAKE DAM	AMUSEMENT	Joy, serenity, Calmness (DOGS OFF LEASH)	6	100M
UPPER LAKE BRIDGE PATH	PLEASURE	Amusement, distraction (BEAUTY OF NATURE)		
LOWER LAKE PATH	ANNOYANCE	DOGS NOT ALLOWED TO SWIM LITTLE BEACH. LOWER LAKE	7	100M
	AMUSEMENT	COMPLETION OF WHOLE AREA	7	101M
RESERVOIRS	SATISFACTION	WATER SUPPLY KEPT AVAILABLE/CLEAN	7	10M.
BIG ROCKS (WITH MOSS ON PATH SHADED)	JOY	BEAUTY OF NATURE	7	100M

Main Purpose for Today's Visit: Walking ☒ Running ☐ Walking Dog ☒ Swimming ☐ Sunbathing ☐ Commuting ☐ Cycling ☐ Fishing ☐ Other ______

How many years have you been visiting this park: Less than 1 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5-7 ☒ 8-10 ☐ More than 10 ☐

How often do you visit the park: Daily ☐ Several Times a Week ☒ Weekly ☐ Every 2 Weeks ☐ Monthly ☐ Infrequently ☐

7 = Very Important
6 = Important
5 = Somewhat Important
4 = Neutral
3 = Somewhat Unimportant
2 = Unimportant
1 – Very Unimportant

In this section, we would like to collect some information about you to help us determine whether males, females or people in different age categories or ethnic groups see their parks differently. We are requesting your postal code so that we can determine roughly where you live in relation to the park. If you are not a resident of British Columbia, please enter "outside" as your Postal Code.

Age: 49 | Gender: M ☐ F ☒ | Postal Code: V9S 1C7 | Occupation: PHYSIOTHERAPIST

What is the highest level of education that you've completed: Elementary ☐ Secondary ☐ University/College ☒ University Postgraduate ☐

If you wish to be identified as a member of an ethnic group, please write it here (optional):

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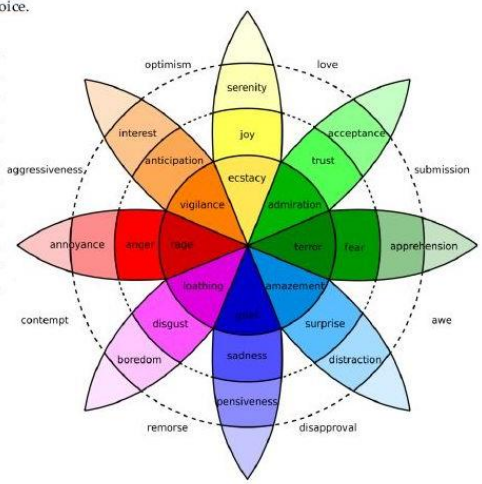
Figure 3.4. Main survey questionnaire filled out by participant 362199345. Note that there is an error, even in this well-done form – both walking and walking dog have been filled out as the main purpose.

Choice of Emotions

Please point to the emotion in the diagram to the right or in the list below which best describes how you feel about a park feature. If you cannot find your emotion here, a complete list of emotions is available.

"No Emotion" is also a perfectly valid choice.

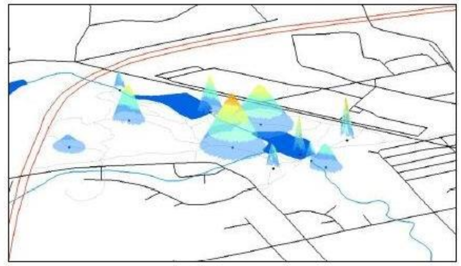
Amusement	Calmness
Closeness	Completion
Curiosity	Discovery
Excitement	Friendship
Happiness	Hopefulness
Incorporation	Innocence
Intimacy	Nostalgia
Pleasure	Pride
Relaxation	Satisfaction
Sentimentality	Togetherness
Wonder	



Awareness Distance

For a particular feature (object, place, area), the awareness distance is:

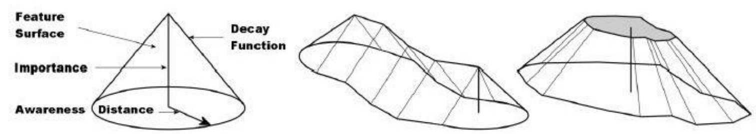
- **How close you must be before you become aware of it when approaching, or**
- **How far away you must be before you lose awareness of it when you are leaving.**



In this project, we are attempting to map a surface that shows your knowledge and appreciation of park features. The illustration to the right shows how we construct a surface from the individual features mentioned during an interview.

For example, for a child, the awareness distance for a piece of playground equipment might be a few metres (the distance between adjacent pieces of playground equipment). For his or her parent, the awareness distance for the might be 100 metres for the same feature (the distance within which a child can be supervised). At a viewpoint, the awareness distance might extend as far as you can see.

The awareness distance is used to define the "extent" of a particular feature in the park. We base the height on the emotional and logical importance of the feature, and this importance decreases to zero or a constant (low) value at the awareness distance.



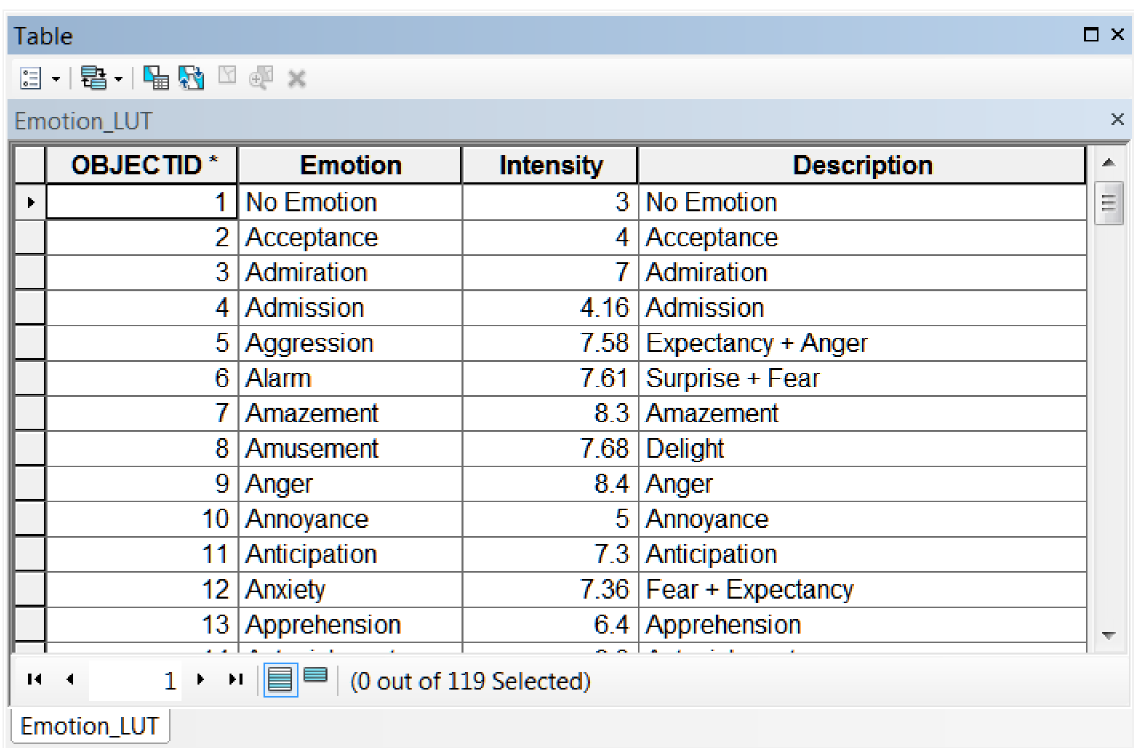
Example Awareness Distances:

Distance (m)	Distance (ft.)	Meaning
3	10	Width of Parkway Trail, Close Supervision of Children
8	26	Supervision of Children
15	41	Length of Upper/Lower Bridges, 10 Second Walk
20	66	Width of Grassy Swimming Area at Lower Dam
40	131	Average Lot Length in Nanaimo, 30 Second Walk
100	328	Approximate Width of Lower, Upper Lakes
200	656 (~1/10 mile)	Approximate Length of Lower, Upper Lakes
V	Visible Range	

Figure 3.5. The emotion (left) and awareness distance (right) cards that were provided to participants to assist them with filling in the survey questionnaire.

wheel of emotions (Plutchik, 1962), and additional emotions suitable for a park environment were shown in a table of emotions drawn from Plutchik's dictionary (Plutchik, 1980). A majority of users appeared to choose their emotion from Plutchik's wheel, possibly because its bright colors attracted their attention. If a participant mentioned an emotion that was not described on the reference card, the software allowed any of the 118 emotions defined in Plutchik's dictionary to be chosen.

Each of the 118 emotions comes from the Plutchik (1980) model of the emotions (Appendix A) and is stored together with its affect value in a database table within the PAS (Figure 3.6). The affect derived from the emotion is used as an estimate of place identity.



OBJECTID *	Emotion	Intensity	Description
1	No Emotion	3	No Emotion
2	Acceptance	4	Acceptance
3	Admiration	7	Admiration
4	Admission	4.16	Admission
5	Aggression	7.58	Expectancy + Anger
6	Alarm	7.61	Surprise + Fear
7	Amazement	8.3	Amazement
8	Amusement	7.68	Delight
9	Anger	8.4	Anger
10	Annoyance	5	Annoyance
11	Anticipation	7.3	Anticipation
12	Anxiety	7.36	Fear + Expectancy
13	Apprehension	6.4	Apprehension

Figure 3.6. Lookup table for emotions showing the emotion name and its affect (intensity). The affect values are automatically transferred to the features when they are tagged with a particular emotion. Note that "No Emotion" is included in this table, which is why there are 119 emotions listed, rather than the 118 that Plutchik defined.

Next, participants were asked to enter the reason for importance or comments for each feature. This was freeform text with no length limit, and was used to create a database of qualitative information that was tied to each feature in the PAS. The data provided on the paper form was entered into the PAS with as little alteration as possible. The only limitation was that they had to be entered by keyboard, so illustrations or unusual symbols could not be stored in the database. In such cases, notes were added in parentheses to describe what was found on the paper form. The data in this column is not currently analyzed, although it can be easily examined to obtain contextual information about the features being described. In future, this data may be analyzed using qualitative analysis software.

In the Importance column, participants were asked to rate the importance of each feature on a 7-point Likert scale. A value of 7 represented "Very Important," 4 represented "Neutral" and 1 represented "Very Unimportant" (Figure 3.4, p. 69). The importance was used as a measure of place dependence, which is the second component of place attachment (Williams & Vaske, 2003).

Participants were next asked to enter their ***awareness distance***, the distance at which their awareness of the feature being described faded to background levels. Whereas people may retain a memory of a feature anywhere they travel, beyond the awareness distance, there needs to be a reminder of that feature for them to recall it. Within the awareness distance, the influence of the feature itself is strong enough that people are regularly aware of it. Participants who lived near the park reported that they were always consciously or subconsciously aware of the features being described, no matter where they were located. This may be because their place attachment was particularly high, and the features had become intertwined with their biography (Pred, 1984). For these people, the park is essentially an extension of their backyard. In this case, the awareness distance extended as far as their home.

On the information card that we provided to participants (Figure 3.5), the awareness distance was defined as "How close you must be before you become aware of it [a particular feature] when approaching or how far away you must be before you lose awareness of it when you are leaving." In other words, it is the distance from the feature at which place attachment becomes insignificant. This may be expressed in any unit of measure that can be converted to meters. When participants failed to supply an awareness distance for a feature, the mean awareness distance for all features described (1276 m, 1395 yd.) was employed.

On the survey questionnaire, participants were also asked to provide their age, gender, ethnicity, occupation and level of education. Postal codes were also collected so that the participants' neighborhoods could be identified. On the second page of the survey, a simple base map was provided for participants to annotate. Seventy-four participants (24.5 %) took advantage of this and submitted supplemental sketch maps (Figure 3.7, left). On the final page of the survey, the researcher noted the date, time, location of data collection and the weather conditions at the time of collection (Figure 3.7, right).

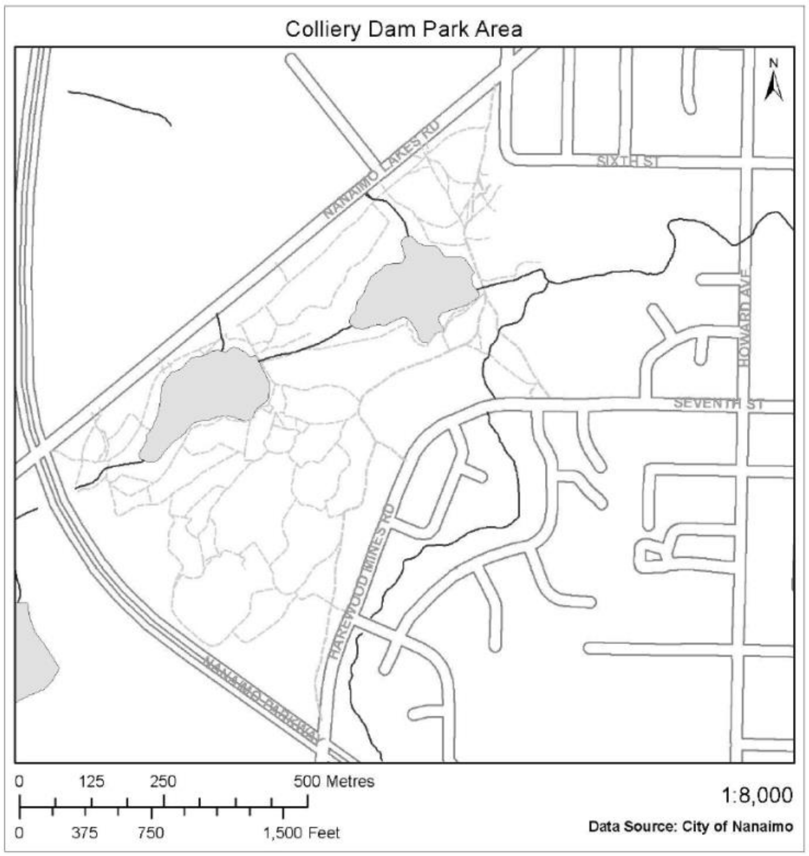
3.4.6 User Interface

The PAS data entry interface was designed to mirror the paper form, allowing for direct entry of data during the survey, and to reduce the probability of transcription errors (Figure 3.8). It is relatively easy to spot errors when the interface is similar to the paper form; the program

Questionnaire PlaceInGIS.com Participant 362199345

<u>To be Completed by Participant</u>

Sketch Map (Optional). *Outline the boundary of Colliery Dam Park and fill in the details of any features that you wish to describe. Please label the features with the Feature Name listed on the previous page.*



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Questionnaire PlaceInGIS.com Participant 362199345

<u>To be Completed by Researcher</u>

Date/Time YY 1 MM DD HH MM ☐a.m. ☐p.m.

Data Collection Location

- ☐ Location 1 – Lower Dam
- ☐ Location 2 – Upper Dam
- ☐ Location 3 – Lower Parking Lot
- ☐ Location 4 – Upper Parking Lot
- ☐ Location 5 – Parkway Trail Intersection
- ☐ Location 6 – Trail Off Seventh Avenue

Entrance Used by Participant

- ☐ Entrance 1 - Lower Parking Lot
- ☐ Entrance 2 - Upper Parking Lot
- ☐ Entrance 3 - Parkway Trail, North Entrance
- ☐ Entrance 4 - Seventh Avenue
- ☐ Entrance 5 - Harewood Mines Road
- ☐ Entrance 6 - Parkway Trail, South Entrance
- ☐ Unknown

Weather Conditions at Time of Survey

Temperature ____ °C

Amount of Cloud ______% (to nearest 10%)

Rain Y ☐ N ☐

Wind Y ☐ N ☐

Sun Y ☐ N ☐

Selection Method

Random Selection ☐

Self-Selection (Voluntary) ☐

Invited by Researcher ☐

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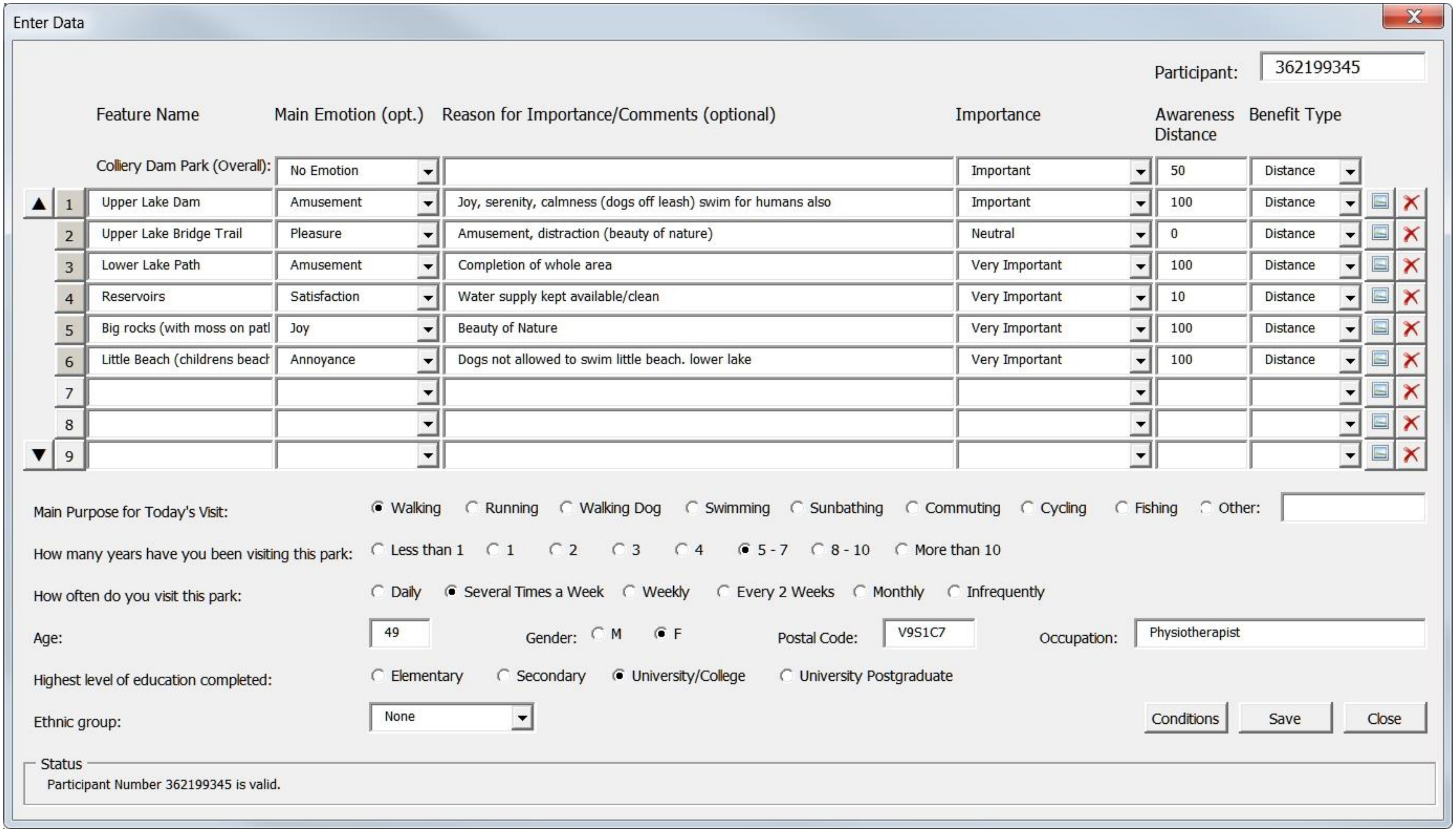
Figure 3.7. Optional supplemental sketch map (left) and survey conditions form to be filled out by the researcher (right)



Enter Data

Participant: 362199345

	Feature Name	Main Emotion (opt.)	Reason for Importance/Comments (optional)	Importance	Awareness Distance	Benefit Type
	Colliery Dam Park (Overall):	No Emotion		Important	50	Distance
1	Upper Lake Dam	Amusement	Joy, serenity, calmness (dogs off leash) swim for humans also	Important	100	Distance
2	Upper Lake Bridge Trail	Pleasure	Amusement, distraction (beauty of nature)	Neutral	0	Distance
3	Lower Lake Path	Amusement	Completion of whole area	Very Important	100	Distance
4	Reservoirs	Satisfaction	Water supply kept available/clean	Very Important	10	Distance
5	Big rocks (with moss on patl	Joy	Beauty of Nature	Very Important	100	Distance
6	Little Beach (childrens beach	Annoyance	Dogs not allowed to swim little beach. lower lake	Very Important	100	Distance
7						
8						
9						

Main Purpose for Today's Visit: (•) Walking ( ) Running ( ) Walking Dog ( ) Swimming ( ) Sunbathing ( ) Commuting ( ) Cycling ( ) Fishing ( ) Other:

How many years have you been visiting this park: ( ) Less than 1 ( ) 1 ( ) 2 ( ) 3 ( ) 4 (•) 5 - 7 ( ) 8 - 10 ( ) More than 10

How often do you visit this park: ( ) Daily (•) Several Times a Week ( ) Weekly ( ) Every 2 Weeks ( ) Monthly ( ) Infrequently

Age: 49 Gender: ( ) M (•) F Postal Code: V9S1C7 Occupation: Physiotherapist

Highest level of education completed: ( ) Elementary ( ) Secondary (•) University/College ( ) University Postgraduate

Ethnic group: None

Conditions Save Close

Status

Participant Number 362199345 is valid.

Figure 3.8. A digital representation of the paper form (Figure 3.4, p. 69) was used to reduce the possibility of transcription errors. The data provided by participant 362199345 is shown.

also performs validity checks (e.g., incorrectly formatted postal codes are automatically rejected).

3.4.7 Storage of Survey Data

Once the data have been entered into the Data Entry form in the PAS, they are automatically transferred from the form to the correct relational database tables for later analysis. The columns in the Data Entry form are processed as follows (see Appendix C):

- **Feature Name:** The name of the feature, in the words of the participant. This is placed into the Given_Name column in the Mainform_Features table.
- **Main Emotion:** Any one of the 118 emotions described by Plutchik (1980). Each emotion is automatically associated with its affect value, and the affect value is stored in the Emotional_Int column in the Mainform_Features table as the measure of place identity. Data for the 118 emotions available for this column comes from the Emotion_LUT table (Figure 3.6, p. 71).
- **Reason for Importance/Comments:** Qualitative data to help us identify and understand why the features are important to the participants. This is placed into the Imp_Because column in the Mainform_Features table.
- **Importance:** The importance of the feature, on a scale of 1-7 (Very Unimportant to Very Important). This was the measure of place dependence. This is placed into the Feat_Importance column in the Mainform_Features table.
- **Awareness Distance:** The distance (in meters) from the edge of the feature to the point where the feature is not spontaneously recalled, unless the participant is reminded of it. This is placed into the Benefit_Dist column in the Mainform_Features table.
- **Benefit Type:** The way the distance is described, either Distance (D) for a numerical value in meters, or Visual (V) for a value based on the viewshed surrounding the feature. Only the Distance option is currently used. This is placed into the Benefit_Type column in the Mainform_Features table.

These data are permanently stored in the PAS in their raw form to ensure the integrity of the results produced; all analyses are based on these raw data with the exception of place attachment surfaces that are generated for each participant. This reduces the amount of processing required for analysis of the surfaces.

Appendix A contains a diagram showing the main tables used in the PAS. The main tables that are used in the system are:

- **Mainform_Features**: A table that stores the features described by the participant, with the place dependence, place identity, and place attachment value for each feature. This table is indexed by the 9-digit participant number, but an additional *OBJECTID* key is also used by *Mainform_Multiobject*.

- **Mainform_Multiobject**: A table that identifies the lines, points and polygons on the map that make up a single feature in *Mainform_Features*. *Mainform_Multiobject* contains two keys: *Feature_OBJECTID*, which matches the *OBJECTID* key in *Mainform_Features*, and *Feature_ID*, which matches the *Feature_ID* key in *Object_LUT*. If, for example, the participant describes "trails" in *Mainform_Features*, *Mainform_Multiobject* has links from the unique *OBJECTID* for this feature to the 243 individual trail segments identified in *Feature_ID*.

- **Object_LUT**: This look-up table contains all cataloged objects including their name, description, type and source layer so that they can be extracted for use during data processing. This table uses *Feature_ID* as its main key (see Figure 3.6, p. 71).

- **Mainform_Participant**: This table stores the demographic and visitation data for each participant. This is indexed by the 9-digit participant number.

- **Mainform_Questionnaire**: This table stores data about the participant and data collection information, particularly the rejection flag and reason, which explains why a participant's submission has been rejected. This table is indexed by the 9-digit participant number.

The use of the keys in these tables allows them to be kept reasonably small, since they represent only one class of data, but they also permit great flexibility, as the tables can be temporarily connected using an attribute join with matching keys when required for analysis.

3.4.8 Visual and Numerical Distances

Initially, during the design of the survey, we only focused on numerical values (those based on an estimated distance or a travel time) for the awareness distance. However, during the pre-test of the survey, several participants commented that they thought of features only when they were visible. Based on this input, we decided to add a column to permit users to enter either a "D" for an estimated distance in meters or a "V" for a distance based on where a feature was visible. Unfortunately, when we rolled out the final survey form, we found that the "V" option was more popular than we had anticipated, because it took little or no time and effort for participants to enter a "V," whereas entering a "D" and an estimate of the distance was more involved. Fortunately, in spite of this, the participants used the estimated distances more often than the distance where the feature was visible. The rate of estimated distance use was highest (85.4%) for those who had used the park for the longest period and lowest for those who had visited the park for the shortest period (71.3%).

Although we were able to produce viewsheds (the area in which a feature is visible) for the "V" features, this approach was eventually abandoned. Instead, the PAS was modified to process any "V" entries as a distance using the mean of numerical distance values given by other participants. The place attachment surfaces created from the viewsheds took a long time to create, had complex shapes and were very difficult to interpret and verify statistically.

3.5 Plutchik's Model

Robert Plutchik's (1980) psychoevolutionary model of the emotions provided a dictionary of emotions that were used in this study. Because Plutchik's model provides a large number of emotional terms with each having a corresponding numerical affect value, this work provides an important link between the qualitative and quantitative aspects of this research. Plutchik's affect values are based on empirical research, in which a group of research subjects was asked to rate each emotion on an 11-point Likert scale, with 1 being very low intensity, 6 being moderate intensity, and 11 being the highest intensity (Plutchik, 1980). In practice, Plutchik found that emotions with intensities below 3 were indistinguishable from one another (see Appendix A).

Plutchik (1980) defined both primary and secondary emotions. Primary emotions were derived from the four axes in Plutchik's wheel of emotions: fear-anger, joy-sadness, acceptance-disgust and expectancy-surprise (See Figure 3.5 left, p. 70). Secondary emotions were defined as the combination of two primary emotions. Plutchik did not define affect values for all secondary emotions; in such cases, we took the mean of the affect values for the two contributing primary emotions. It is important to note that Plutchik's affect values were not valenced, such that ecstasy (10.00) has a similar affect to terror (10.13) (Plutchik, 1962). This model worked acceptably well in a park where virtually all emotions were positive, but might need to be replaced for future research where people have more ambivalent emotions.

During the design of the survey, it was considered important that there be a wide variety of emotions to choose from, and Plutchik's model offered the largest variety of emotional terms, each with an associated activation value that could be used to quantify the emotional reaction of the participant to particular features mentioned. While the survey was being conducted, it became apparent that relatively few emotions were being mentioned by participants. This seemed to be mostly the result of a disconnect between the academic nature of Plutchik's work (118 emotions was too specific) and the level of emotional literacy in the general population (few people are able to describe what an emotion such as "completion" or "set" feels like). Even more common emotions such as "fatalism" or "forlornness" might be beyond the vocabulary of many park users, 31% of whom reported not having a university education and many of which speak English as their second language.

3.6 Calculation of the Place Attachment Value

Williams and Vaske (2003) were able to show that place identity and place dependence together constitute most of place attachment, and that these dimensions only have a small degree of overlap. There are also two other minor dimensions that do not contribute significantly to this model. Place identity "refers to the symbolic importance of a place as a repository for emotions and relationships that give meaning and purpose to life" and place dependence "reflects the importance of a place in providing features and conditions that support specific goals or desired activities" (p. 831). Place identity represents an affective (emotional) understanding, whereas place dependence represents a cognitive (logical) understanding (Jorgensen & Stedman, 2011). This model is one of the foundations of the PAS, allowing us to create place attachment surfaces from the inputs provided by each study participant.

Using the place attachment model, we can combine the place dependence and place identity components to come up with an overall place attachment value. In Equation 3.1 the [3,11] interval for place identity (emotional affect) is combined with the [1,7] interval for place dependence (cognitive importance), to create a single formula for place attachment.

$$\boldsymbol{A = \frac{7}{9}(I - 2) + D}$$ **Equation 3.1**

Where:
A is the place attachment value;
I is the place identity; and
D is the place dependence of the feature.

In this equation, place identity (9 values – [3,11]) is weighted so that it is equal to place dependence (7 values – [1,7]). Substituting the minimum and maximum possible place identity and dependence values into Equation 3.1 produces an interval of [1.7…,13.323…] for place attachment values.

In Equation 3.1, the place identity values are adjusted so that they are equal in weight to the place dependence values. Williams (2016) points out that place identity is an emotional concept whereas place dependence is a logical concept, an assertion that is supported by the Factor Analysis that showed little overlap between these concepts. These values are epistemologically separate, and thus cannot be valued in relation to each other. The only way to deal with these is to treat them as separate, but equal concepts, which is the approach that other researchers have followed (Williams, 2016).

3.7 Creation of a Place Attachment Surface

Unlike traditional (discrete) representations of points, lines and polygons, we have replaced the discrete boundaries of features with fuzzy boundaries that decrease over distance. Rather than having a polygon with a single place attachment value, and an abrupt change to background values at the polygon's edge, we have a polygon with a single place attachment value, but a gradual transition to background values outside the polygon (Figure 3.9). The same principle applies to points and lines.

The feature surfaces created are combined into a place attachment surface with a fuzzy union operator. The study participant is never required to draw a line to demarcate the boundary of a place; boundaries for different participants can be created using standardized methods. This

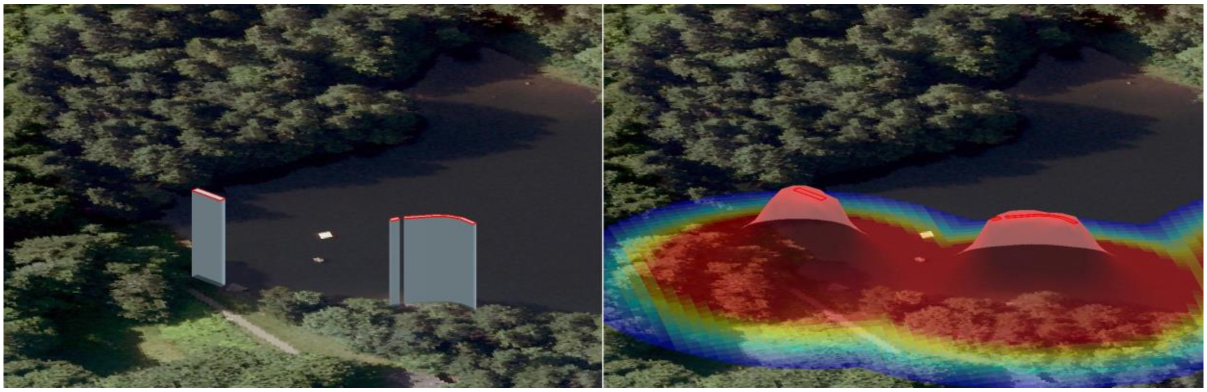


Figure 3.9. Traditional (discrete) polygon representation of fishing areas within GIS versus fuzzy representation employed in the PAS. The polygons represent three fishing areas at the lower Colliery Lake described by Participant 015963963. The background value of 1.77 is not shown for clarity.

allows for the comparison of place attachment surfaces, which can be used to determine areas of agreement and contention. We can also combine multiple surfaces to determine consensus opinions for the population or for selected samples of participants. There are a number of steps that are required to create a place attachment surface, beginning with the construction of a Euclidean distance raster.

3.7.1 Calculation of a Euclidean Distance Raster

A Euclidean distance raster is calculated outwards from the edge of each feature to the awareness distance using ***map algebra***. In each cell of the Euclidean distance raster, the distance from the edge of the feature to the center of the cell is automatically recorded by ArcMap, providing the distance ($d_{i,j}$) value that is necessary to calculate the height of the surface for each pixel in the raster. A map algebra expression can then be used to calculate the height of the raster ($Z_{i,j}$) from the distance value ($d_{i,j}$) to create a logarithmic surface.

3.7.2 Logarithmic Surface Formula

The curve of the decay surface is based on research about how memories of emotions decay with distance. Ekman and Bratfisch (1965) observed that the emotions related to a place follow a logarithmic decay with an asymptote greater than zero. They initially proposed that the relationship between emotional involvement and distance followed an inverse square law, but the exponent was later refined by Dornič (1967) to yield Equation 3.2:

$$\boldsymbol{Z_{i,j} = d_{i,j}^{-0.47}} \qquad \textbf{Equation 3.2}$$

Where:
$Z_{i,j}$ represents the value of the decay surface; and
$d_{i,j}$ is the subjective distance from the feature.

This equation produces a curve that is quite useable, except that when $d_{i,j}$ approaches 0, $Z_{i,j}$ approaches infinity, so it is necessary to modify this curve somewhat for use in a computer program.

3.7.3 Creating a Normalized Logarithmic Surface

Based on Equation 3.2, we create a normalized logarithmic surface with the correct curvature, but which has a value of 1.0 at the center, and 0.0 at and beyond the distance specified by the participant (Equation 3.3).

$$\boldsymbol{M_{i,j}} = \begin{cases} \mathbf{1} & if\ d_{i,j} = 0 \\ \dfrac{\boldsymbol{d_{i,j}}^{\mathbf{-0.47}} - \boldsymbol{d_{awareness}}^{\mathbf{-0.47}}}{\boldsymbol{d_{min}}^{\mathbf{-0.47}} - \boldsymbol{d_{awareness}}^{\mathbf{-0.47}}} & if\ d_{i,j} \leq d_{awareness}\ and\ d_{i,j} > 0 \\ \mathbf{0} & if\ d_{i,j} > d_{awareness} \end{cases} \qquad \textbf{Equation 3.3}$$

Where:
$M_{i,j}$ is the multiplier value for the place attachment surface;
$d_{i,j}$ is the Euclidean distance recorded in the pixel (km);
$d_{awareness}$ is the awareness distance expressed by the study participant (km); and
d_{min} is the minimum possible distance (km).

For each feature, the place attachment value is calculated and multiplied by the $M_{i,j}$ value. The resulting feature surface thus decays outward from 1 to 0 as distance increases from the feature. The behavior of this function is shown in Figure 3.10.

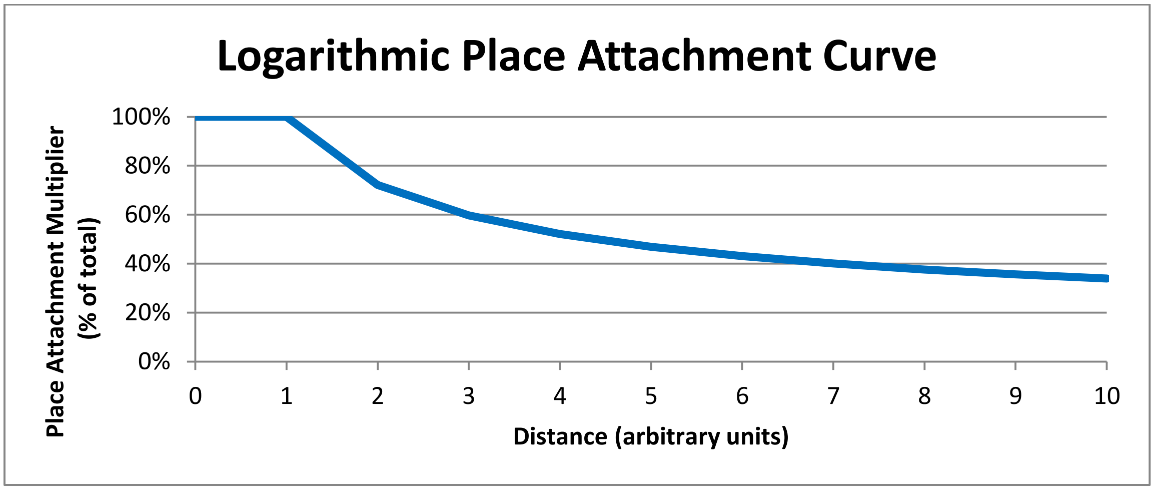


Figure 3.10. Example decay curve based on Equation 3.3. Notice how the logarithmic curve becomes flatter as the distance increases, so it is asymptotic to 0%, becoming ever closer without actually reaching the value. The curve shape is logarithmic, which matches the profile of the surface in Figure 3.9 right, p. 82.

Because the function is asymptotic to zero, it supports Massey's (1997) assertion that places have no boundaries since such a surface extends around the globe. Inverse square functions are common in nature, so it is not surprising that Ekman and Bratfisch initially chose such a function. Both light and gravity follow such a function, in which the strength of the phenomena decreases with the square of the distance. However, there is no reason why a psychological function should behave in exactly the same way as a physical function, so the modification of the exponent from -0.5 to -0.47 by Dornič is not surprising.

Initially, we experimented with the ability to create different decay curves (logarithmic, exponential, Gaussian, linear, logistic, hyperbolic tangent, and discrete based on viewsheds). During initial testing, we worked with a linear decay model. However, it soon became apparent that the logarithmic curve was the correct approach, given what had already been published (Dornič, 1967; Ekman & Bratfisch, 1965) and intuitively understood by others (Massey, 1997; Pred, 1984; Thrift, 1994; Williams, 2014). The ability to work with different decay curves is still available in the PAS, however the ability to change decay surfaces has been removed from the user interface.

3.7.4 Creating a Feature Surface

To create a feature surface, the surface produced in Equation 3.3 is scaled by the place attachment value to yield a feature surface covering the entire study area. The minimum possible place attachment value (A_{min} = 1.77…) is subtracted from the place attachment value for the feature (A), and all resulting values are increased by A_{min}, to ensure that values range from A at the edge of the feature to A_{min} at and beyond the awareness distance specified by the participant (Equation 3.4).

$$\boldsymbol{A_{i,j} = (A - A_{min})M_{i,j} + A_{min}}$$ **Equation 3.4**

Where:
$A_{i,j}$ is the place attachment value of the feature raster;
A is the place attachment value for the feature;
A_{min} is the minimum possible place attachment value; and
$M_{i,j}$ is the value of the logarithmic place attachment curve from Equation 3.3.

Based on the definition of the awareness distance that we provided, the value supplied by the participant represents the distance from the feature at which the surface reaches its asymptote (1.77…). In other words, once the awareness distance from the feature is passed, the feature no longer actively affects the emotions of the participant, but becomes a distant memory that may be carried with them anywhere in the world, but would only be recalled if some reminder of the feature were present. Figure 3.11 shows the parameters for a feature surface.

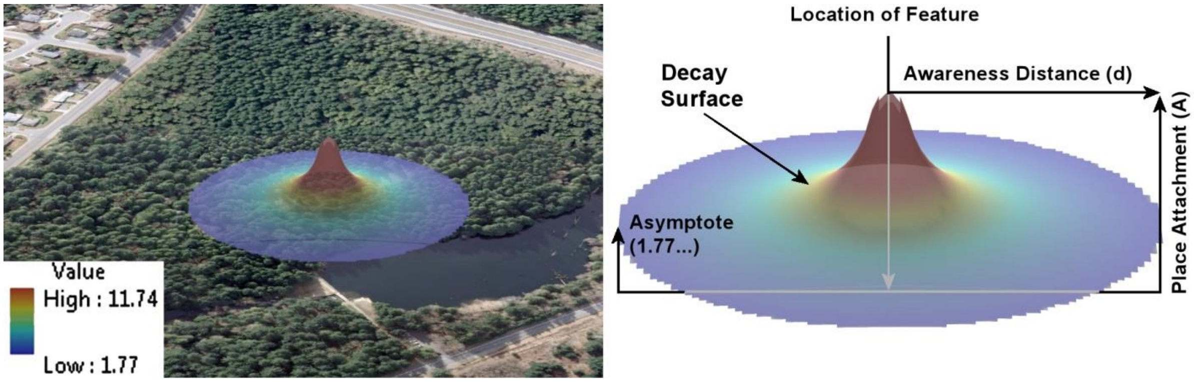


Figure 3.11. Feature surface calculated for the "Big Rocks" described by Participant 362199345, which has a place attachment value of 11.74. The feature surface is viewed from the northeast, and the surrounding areas with the asymptote value have been removed for clarity.

3.7.5 Combining Feature Surfaces to Create a Place Attachment Surface

Because most participants described multiple features, each ended up with many feature surfaces. A fuzzy union function was used to combine them, taking the maximum value of the overlapping surfaces to create a single place attachment surface. This surface can be very complex, given that no limit was placed on the number of objects that could be reported by participants (min. = 1, max. = 16, mean = 3.49). An example place attachment surface showing its constituent feature surfaces is shown in Figure 3.12.

Figure 3.12 provides an example of how an importance surface is built. Of greatest importance are the reservoirs, the main trail providing access to them, and the "Big Rocks" area just to the south of the Upper Lake (Reservoir 2). Of lesser importance are the Upper Lake Dam, the Little Beach on the Lower Lake (Reservoir 1) and the Upper Lake Bridge Trail.

Having a visualization of place attachment can sometimes show unexpected results. For example, in Figure 3.12, the place attachment of the Upper Lake Bridge Trail was much lower than that of the Lower Lake Path. This was surprising, since the trails form a "figure 8"

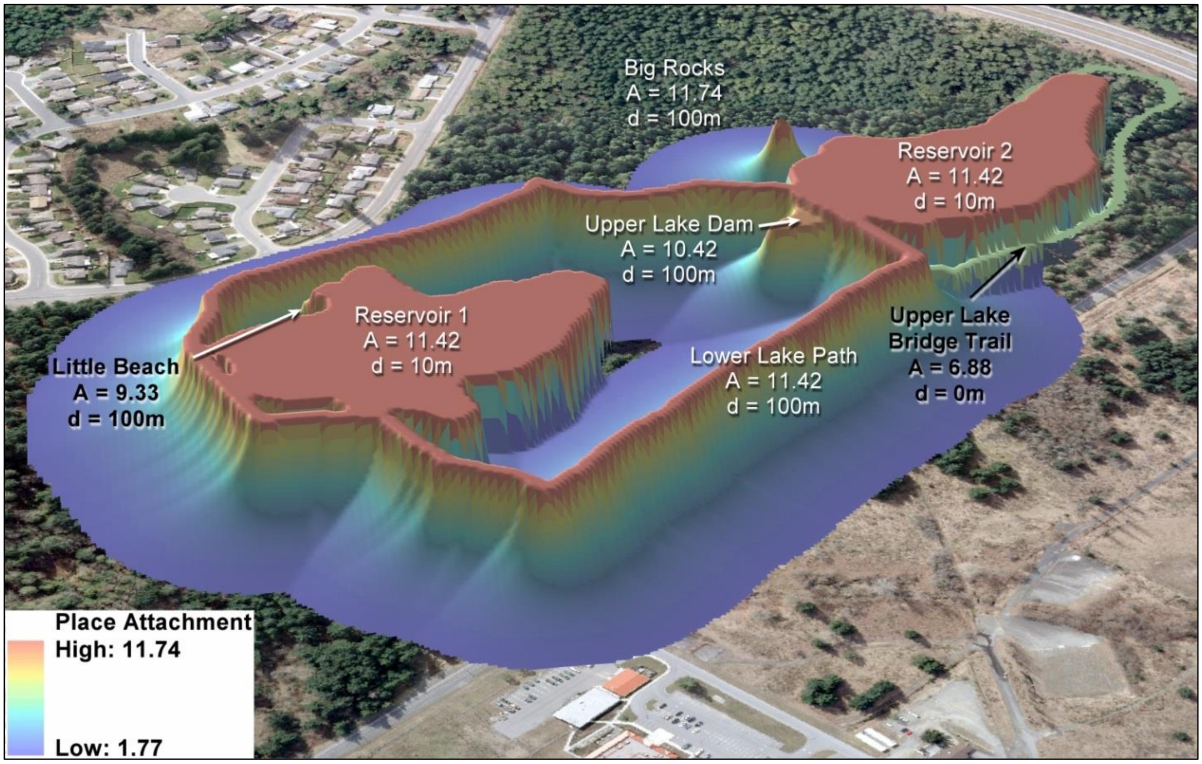


Figure 3.12. Place attachment surface for participant 362199345 viewed from the northeast, showing the contributions made by individual feature surfaces. The place attachment value shown for each feature surface is A and the awareness distance is d. The minimum place attachment value has been removed for clarity.

around the lakes and are frequently traveled in sequence. The place attachment surface shows differences between the two immediately, and allows us to more easily understand the unique perspective of this park user, who strongly favors one trail over the other. This kind of internal detail contrasts sharply with the traditional GIS representation of a place, which would typically be a single uniform polygon with a number of attributes that represent overall values for the park.

3.7.6 Normalizing the Place Attachment Surface

If one participant is particularly emotional, the place attachment surface will have high values; if another participant feels few emotions, their surface will be lower. For this reason, we normalize and scale the place attachment surface to [0,1]. This allows the surfaces created by different participants to be compared meaningfully. Given the theoretical minimum and maximum place attachment values of 1.777… and 13.323…, it is easy to normalize each participant's place attachment surface (Equation 3.5).

$$\boldsymbol{F_{i,j} = \left(A_{i,j} - min(A_{i,j}) \right) / \left(max(A_{i,j}) - min(A_{i,j}) \right)}$$ **Equation 3.5**

Where:
$F_{i,j}$ is the value [0,1] for each pixel in the fuzzy surface raster; and
$A_{i,j}$ is the value of each pixel in the place attachment raster, which ranges from 1.7… to 13.323…

Because the maximum fuzzy surface value for each participant is 1.0, it is possible to compare overall values in the summed fuzzy surface with its theoretical maximum, which will be equal to the number of participants.

3.8 Creation of Summed Surfaces

For the final level of analysis, we generate a summed surface by adding place attachment surfaces together. We can sum surfaces for all participants or for groups based on gender and other demographics (in *Mainform_Participant*) or time and weather conditions (in *Mainform_Questionnaire*). Any set of place attachment surfaces can be selected using the Structured Query Language (SQL), and from these, a summed surface can be created for analysis of group results.

Chapter 4: Place Attachment and Summed Surface Results

In this chapter, we will show how the PAS can be used to visualize and compare place attachment surfaces for individual participants and groups of them, highlighting differences in park use patterns.

4.1 Creating Place Attachment Surfaces

Place attachment surfaces were created for each of the 239 participants. These surfaces help us to understand the unique perspectives of each individual. The construction of the place attachment surfaces is controlled by the information that is entered into the "Enter Data" window.

Each of the place attachment surfaces is based on features that were named by the participant, and may consist of single or multiple features. For instance, the "Water falls" feature described by participant 832284465 refers only to the spillway from the Lower Colliery Dam (Figure 4.1). On the other hand, the "Fishing holes" feature consists of eight distinct areas on the lower and upper colliery lakes. Both the "Water falls" and the "Fishing holes" lead to the generation of separate feature surfaces, which are combined to generate a single place attachment surface. This can be seen below in Figure 4.2b.

Figure 4.1. Enter Data window for participant 832284465.

4.2 Place Attachment Surface Appearance

A selection of four surfaces was chosen to display the variety of attachment surfaces that were created (Figure 4.2).

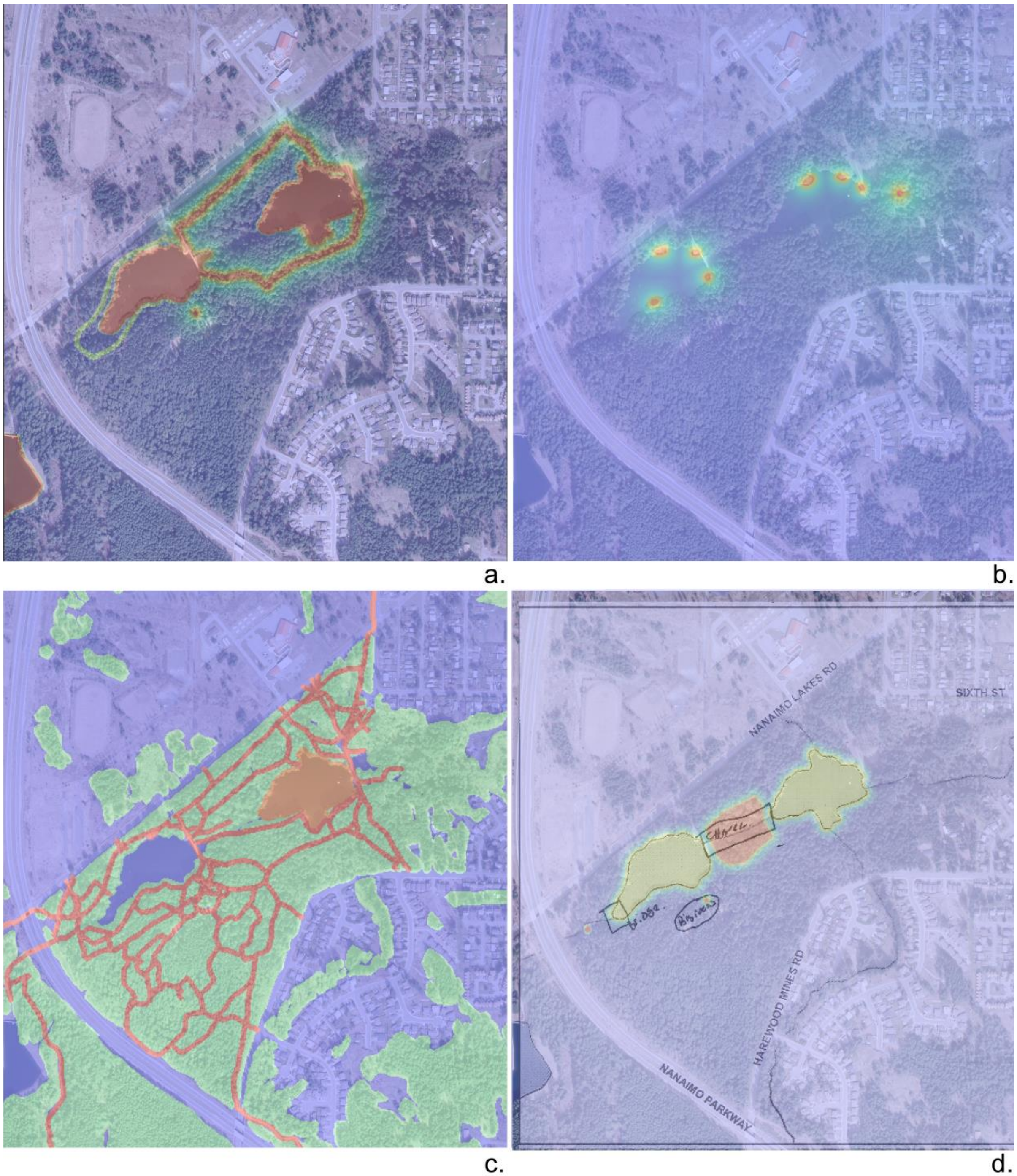


Figure 4.2. Place Attachment surfaces of four individual participants. Redder areas are more important than bluer areas.

Figure 4.2a shows the place attachment surface for participant 362199345. This is a planimetric view of the same surface generated for Figure 3.12 on page 87.

Figure 4.2b (participant 832284465), shows the eight "Fishing holes," as well as the "Water falls" coming from the lower dam spillway (furthest to the east). For the fishing areas, the awareness distance is only 500 ft. (converted to 152.4 m), but for the waterfalls, the awareness distance is 1000 m, so that it merged with the feature surfaces for the fishing areas.

Figure 4.2c (participant 796769349) is focused on the terrestrial features of the park. While the Lower Lake is important to this participant, it is overshadowed by the trail system of the park. The Upper Lake is completely ignored by this participant and the forested areas have only a moderate level of place attachment.

Figure 4.2d (participant 046110296) focuses on the chute that carries water between the upper and lower lakes, as well as the "Big Rock" and a small footbridge that crosses the narrow canyon of the Chase River to the west of the Upper Lake. All of these can be found on the sketch map provided by the participant, which is shown semi-transparently on top of the map. The two lakes within the park are less important to this participant.

Massey (1997, p. 321) states, "If it is now recognized that people have multiple identities then the same point can be made in relation to places." We can see graphical evidence for this statement in Figure 4.2, which shows great differences in the place attachment of different study participants.

Because each place attachment surface is based on a precisely mapped set of features, each is perfectly aligned with every other one generated. This allows the surfaces to be combined, yielding further insights into how individuals and groups of people perceive place. Individual responses can be compared by subtracting one place attachment surface from another. In Figure 4.3, the response of Participant 046110296 (Figure 4.2d) has been subtracted from the place attachment surface for participant 362199345 (Figure 4.2a) to generate a surface showing the areas of agreement (values close to zero) and disagreement (values with strong positive or negative values). We can see that participant 362199345 mentions a number of areas ignored by participant 046110296 (bright red), places a higher value on others (medium red), and is in agreement for most areas (yellow). Participant 046110295, conversely mentions some areas ignored by participant 362199345 (bright blue), or emphasizes others more strongly (medium blue). Presenting a diagram such as this to both participants can be used to invite discussion about which areas are important, why they are important, and to what degree they are emphasized by each study participant.

4.3 Summed Surface Appearance

We can also combine surfaces to obtain an average view for a group. When even a few place attachment surfaces are combined to create a summed surface, the result can be difficult to describe except in map form. A summed surface does not represent a consensus view, since individual participants may disagree on certain features, but it incorporates the views of all participants and shows what areas are valued by the greatest number of people. It is, however, a democratic view, where the "will of the majority" prevails and where the

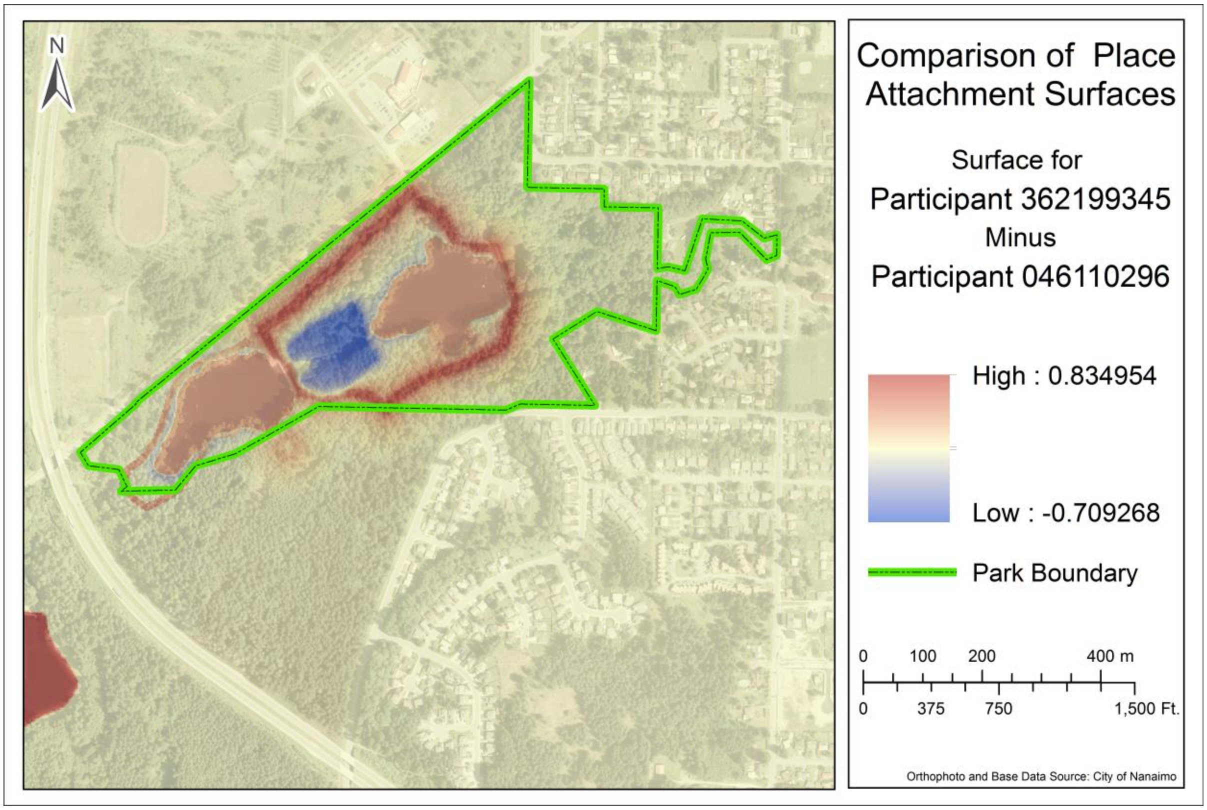


Figure 4.3. Comparison of place attachment surfaces for participants 362199345 and 046110296. Red areas are favored more strongly by participant 362199345, whereas blue areas are favored more strongly by participant 046110296. Notice that this comparison not only factors in the different items of interest, but also highlights differences in the place attachment values and awareness distances surrounding them, even where there is general agreement about the importance of features.

grandstanding and politics that are encouraged by the forced development of a consensus viewpoint may be avoided.

We examined the place attachment surfaces for four groups of participants: all study participants, those participants engaged in a particular activity (dog walking), those participants of a particular age class (>55 years old), and those participants who visited the park during a particular period (December).

The summed fuzzy surface for all participants yielded some unexpected results (Figure 4.4). Although the entire park area had a place attachment that was medium or higher as would be expected, a number of significant areas outside the park boundary were also viewed as being important. The first of these was a forested area within the Nanaimo Military Camp to the north of the park. To the southwest of the park, across the Nanaimo Parkway, another large forested region had medium and high values. In the southeast corner of the study area, an area of undeveloped private land had medium values. Finally, adjoining the park to the south, a large, city-owned lot contained areas of medium and high place attachment.

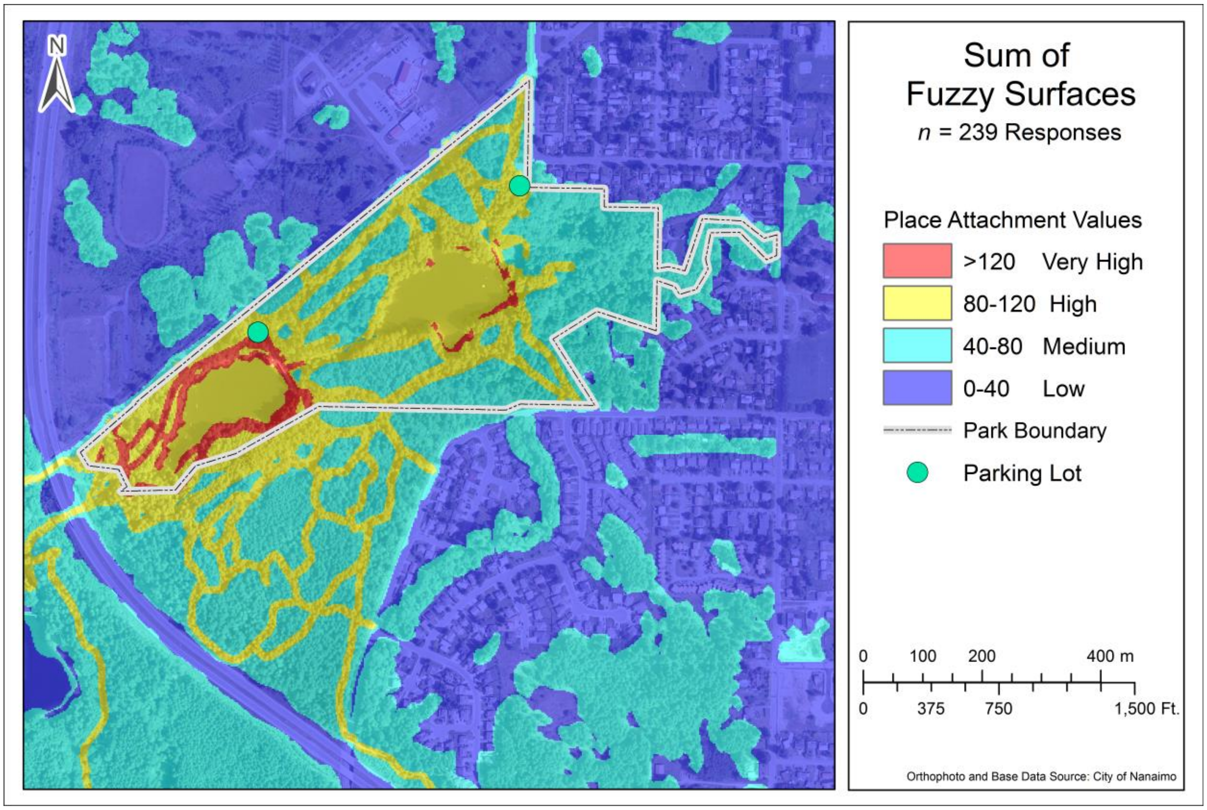


Figure 4.4. Summed surface for all study participants surveyed.

We can see from this that the subjective boundary of "Colliery Dam Park" forms a much larger area than the official boundary. This is supported by informal comments from the study participants, who were generally unaware that the city-owned lot was not legally part of the park. The status of this lot is ambiguous to most participants because the Nanaimo Parkway Trail, a city-owned, paved trail runs through the lot, and there are no signs or barriers to delineate the park boundary in the area.

Another surprising finding is the higher level of place attachment for the Upper Lake than for the Lower Lake. This is surprising, given the density of people at the Lower Lake during the summer, when swimming is a popular activity. However, the difference might be explained because the Upper Lake is used all year round by a large number of dog walkers (26.4% of all participants) who take advantage of the all-weather trails in the off-leash area that surrounds the Upper Lake. In addition, swimmers were relatively under-represented in the survey, totaling only 2.1% of the participants.

An examination of the place attachment of the study area just from the perspective of dog walkers shows the difference between the two lakes (Figure 4.5). Here the emphasis is clearly on the Upper Lake and the off-leash dog area that surrounds it. Less attention is focused on portions of the Lower Lake where dogs swim (contrary to city bylaws) and on the network of trails throughout the park where dogs may be walked on a leash.

Preliminary visual analyses seem to indicate that participants travel into areas with difficult terrain and vegetation less often as they age. Figure 4.6 shows that participants over age 55 have a greater place attachment to the overall park, with one notable exception, which is the area in the east end of the park, which is physically separated from the main part by steep slopes. In the city-owned lot to the south of the park, the place attachment is also reduced, as shown by the incomplete trail network, and patches of medium place attachment. This area is also physically separated from the main park body by cliffs in some areas, and moderate to steep hills in others.

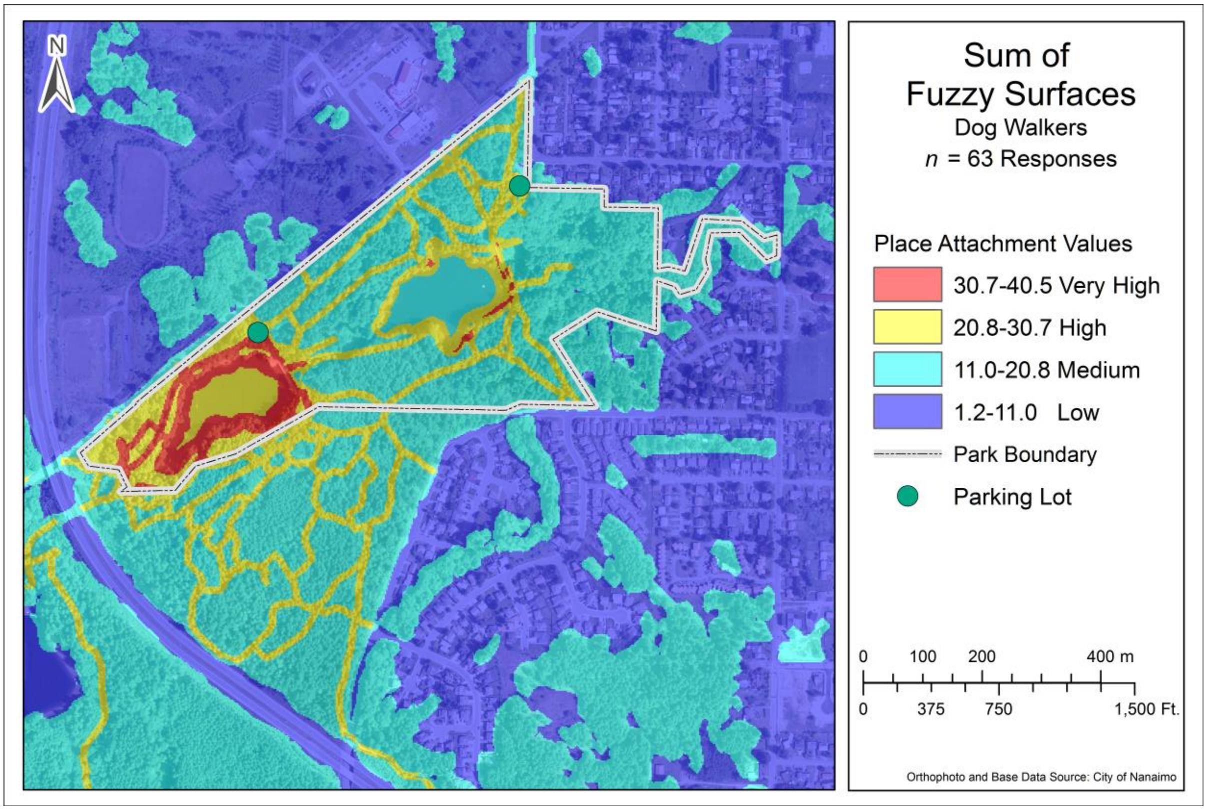


Figure 4.5. Relative place attachment of the upper and lower lakes from the perspective of dog walkers.

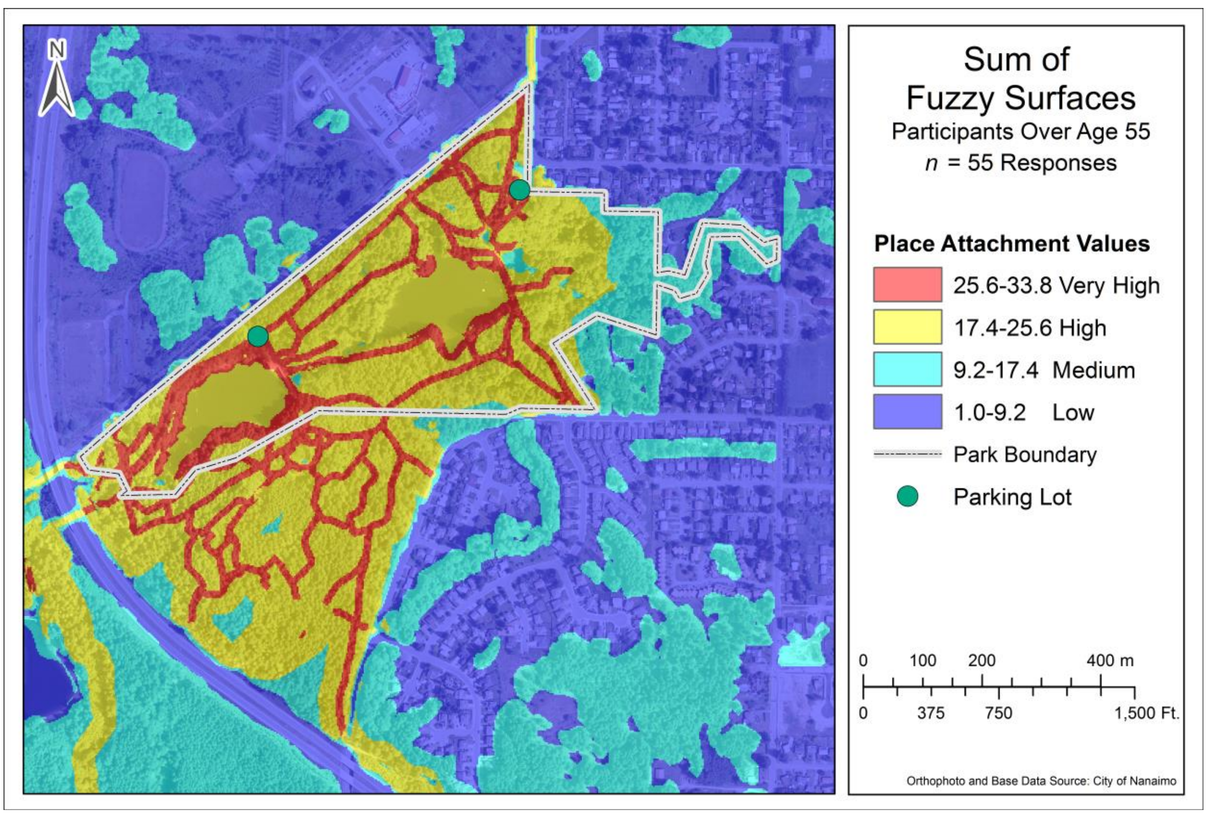


Figure 4.6. Relative place attachment of park areas for participants over age 55.

Similar to the travel constraints caused by topography, we see evidence of constrained travel in the responses that were collected during December, which typically has extended periods of rainy weather (Figure 4.7). The paved Parkway Trail (the discontinuous band of very high values in the eastern portion of the park) shows up distinctly, as do the all-weather trails around the dog off-leash area surrounding the Upper Lake.

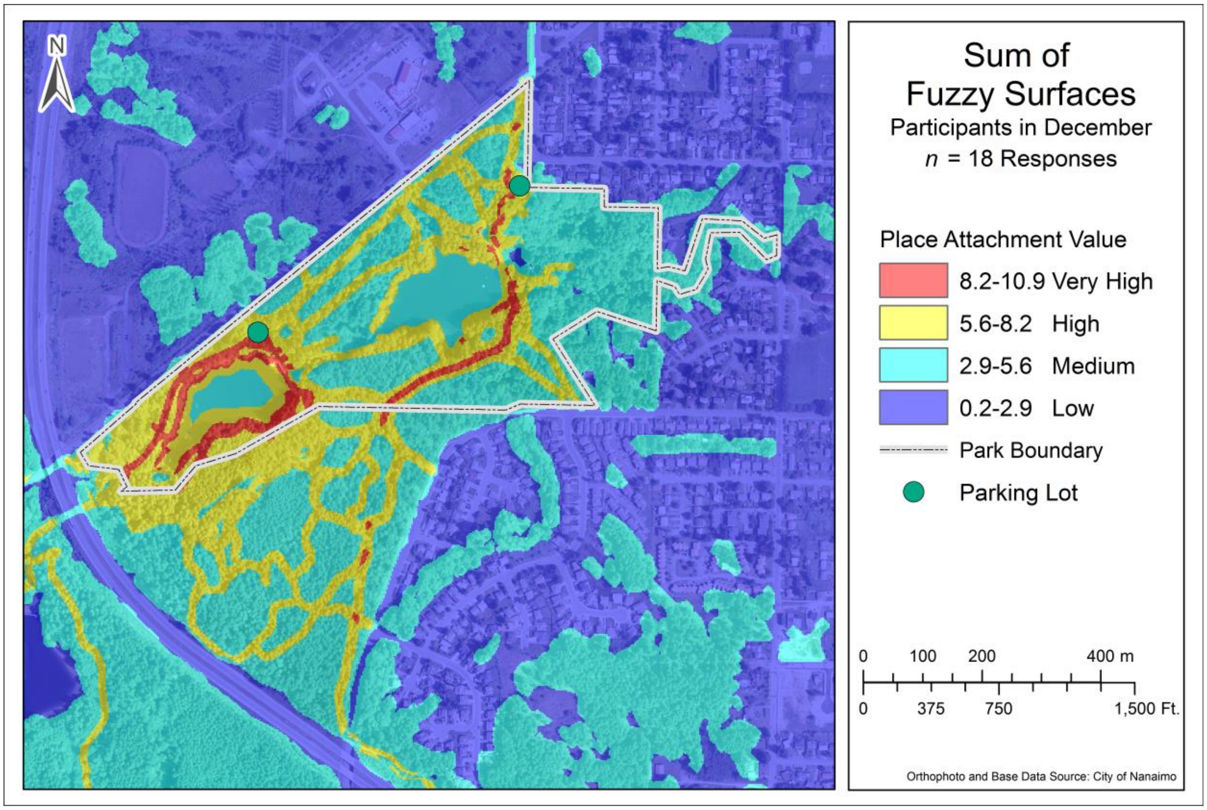


Figure 4.7. Relative place attachment of the study area, as described by the park users who visited the park during December (the middle of the rainy season).

The issue of seasonal and weather-based changes to park use, as we saw in Figure 4.7 leads to some interesting questions about the nature of those changes. To what extent are changes in park use physical, and to what extent are they psychological? Certainly, during cold, wet weather there is a disincentive to travel more than an absolute minimum. There is also the associated issue of the extra work required to dry clothes and clean footwear and pets after the trip. Are participants' impressions of the park less favorable, thus reducing the height of the summed surfaces? The relationships between weather and place attachment are complex and closely intertwined; these could be examined in a future longitudinal study.

We can see from the differences between the previous four figures that the fuzzy surfaces permit a comparison of the place attachment between the entire population of participants and different types of park users (e.g. runners, cyclists, fishers, or swimmers), demographic classes (age, ethnicity), and seasonal users, which offer clues about how park facilities might be improved in the future. For example, Figure 4.5 provides some clues about where facilities for dog walkers (appropriate trails, dog feces collection bag dispensers and trashcans) might be placed.

These initial place attachment surface examples show how the PAS is used to collect, store, and analyze data for a small urban wilderness park at a large map scale. The different patterns that we see for different groups hint at the power this technique has for the analysis of place.

Chapter 5: Validation of Place Attachment Surfaces and Summed Surfaces

The goal of this chapter is to provide support for the method described in Chapter 3. Each design choice has been made against a number of alternatives. In some cases, these design decisions were easy to make, based on previous work done by others, whereas in other cases, there has been no clear path, and finding a solution has required a great deal of reflection, development and testing.

One of the most fundamental questions about the PAS is whether a system that is based on the measurement of place attachment values for individual features within a place can be representative of the place itself. In other words, "Is the whole the sum of the parts?" We address this question first, prior to testing the chain of logic that leads us from those individual features to feature surfaces, place attachment surfaces and finally summed surfaces.

In Chapter 3, we:

- justified the use of *in-situ* sampling;
- described how data were collected from each study participant;
- explained the theoretical basis of how place attachment was calculated from user inputs;
- described how individual features were mapped and indexed so that they could be used to create feature surfaces;
- explained how feature surfaces were created for each feature mentioned by the participant;
- described and justified the ***Fuzzy OR*** process used for combining feature surfaces into a place attachment surface for each participant; and

- described and justified the use of the sum function for combining multiple place attachment surfaces.

Because of the complexity of the software design, a single programming error could break the chain of logic between the inputs provided by the participants and the final surfaces that have been developed from them. Although the software was thoroughly tested at each stage of development, there is still a need to provide independent verification that the outputs from the PAS are representative of the inputs. There are three levels at which such support is important:

1. ***Feature Level*** – for each feature described by a participant, do the parameters of the feature surface reflect the inputs that were provided by the park user?
2. ***Place Attachment Surface Level*** – Can each place attachment surface derived for a participant be shown to be the product of the component feature surfaces? Is there still correlation with the input data provided by the participant?
3. ***Summed Surface Level*** – When summing the place attachment surfaces for subgroups or the complete population of park users, does the summed surface reflect the properties of the place attachment surfaces that were used to create it? Can a correlation still be found between the summed surface and the inputs provided by the participants?

Given the long chain of logic, it is prudent to demonstrate that the results at each level can be shown to have a correlation with the original data provided by the study participants and that advancements from one level to the next are supported. This provides independent statistical validation for the analysis performed in Chapter 3.

5.1 The Importance of Validating the Place Analysis System

In Chapter 3, we built an analytical framework from a foundation that is based on descriptions of individual features by study participants within Colliery Dam Park, the place that we are examining. We described how each study participant provided data for a number of features of importance within the study area. Participants contributed a value for place dependence, and an emotion to describe their place identity. They also gave an awareness distance to indicate at what point they felt that their place attachment became insignificant. These data were then used to construct a fuzzy surface to describe their overall place attachment to the study area.

Using Plutchik's (1980) affect values, we were able to convert the emotion into a numerical value that could be combined with the place identity function to determine an overall index of place attachment, based on the work of Williams and Vaske (2003).

By elevating the features described to the place attachment value calculated for them, we had the beginning of a fuzzy surface describing the place attachment of the participant within the study area. The next step was to define a decay surface to represent the decrease in place attachment as the volunteer moves away from the features described. To do this, we made use of the work of Dornič (1967) to calculate how memories fade as people travel away from the features, until they reach an asymptotic value (for residual memories) at the distance provided by the participant.

Combining the surfaces for each feature mentioned using a Fuzzy OR operator created an overall place attachment surface that shows which parts of the study area have the greatest and least place attachment for each participant. An important feature of these surfaces is that they are based on features that are georegistered, so the place attachment surface is also georegistered as a result. This means that it is possible to combine or compare the surfaces of different individuals directly, allowing the place attachment surfaces to be used for further research.

Because the process of developing and combining place attachment surfaces is complex and relies on custom-designed computer software, it is important to provide confirmation that the outputs correspond with the inputs. It is simply not enough that the software creates results – we must use a number of different methods to ensure that defensible results are being produced.

There are a number of ways that we could validate the results calculated by the PAS. The most obvious is through careful software design and thorough testing. Only with a software engineering approach such as this, can we begin to explore whether the software does what it is designed to do. However, this method is not perfect, and must be supported with other, independent methods.

Our initial independent approach was to compute the results and present them on a website for participant feedback. The ***PlaceInGIS.com*** website (http://www.PlaceInGIS.com) allowed participants to verify that their information was recorded accurately and that the place attachment surface was computed correctly. Volunteers were able to provide feedback using a form on the webpage (Figure 5.1).

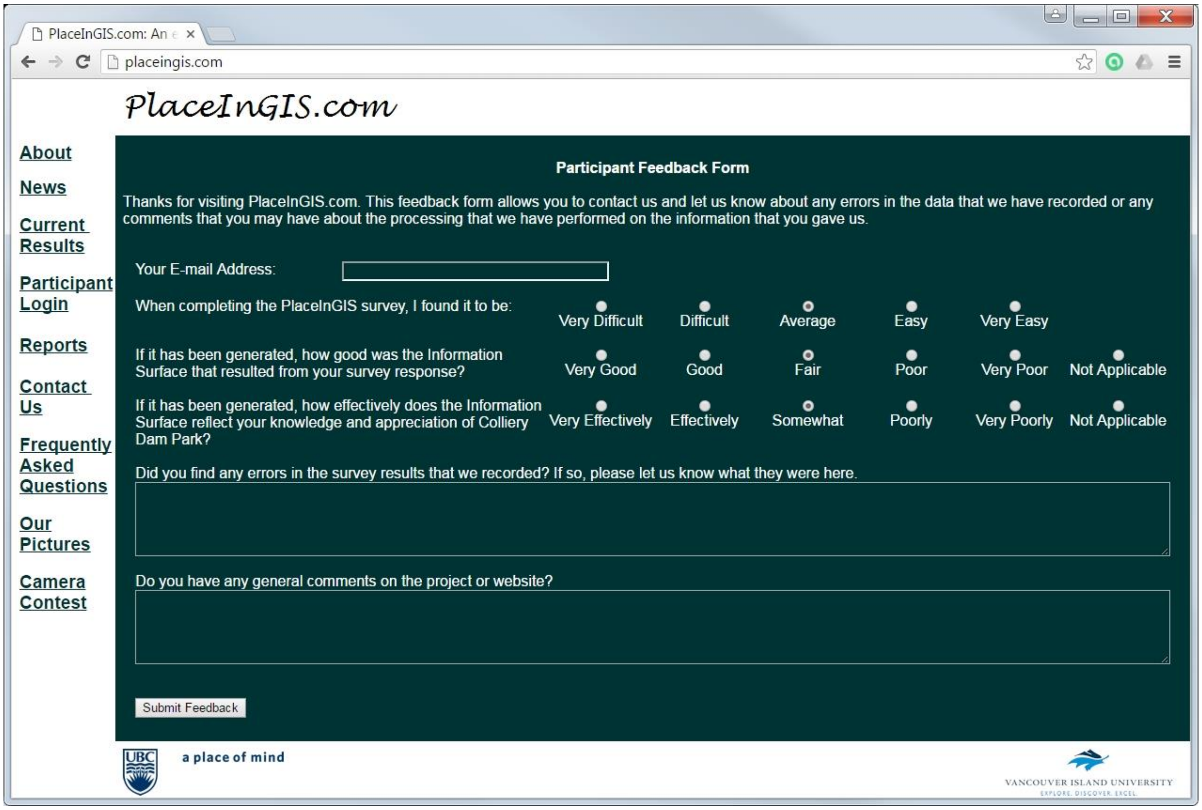


Figure 5.1. Feedback form for each validated participant.

Ethics requirements prevented us from divulging user responses to the public, so users were provided with their randomly assigned 9-digit participant number on their signed consent form; on the website, this was the only way to examine the recorded inputs and the place attachment surface. Unfortunately, only one participant actually logged in and made a comment, so this mechanism was not effective.

Another external approach to validating the place attachment surface is to examine its values in light of the qualitative comments that were made for each feature. Here, a form of lexical analysis would provide an independent measure of the participant's place attachment to each feature. For example, words such as "beautiful" might indicate that a participant has a high degree of place attachment, whereas the addition of a modifier (e.g. "not beautiful") would alter the place attachment significantly. Being able to process descriptive words and modifiers would require sophisticated, contextual analyses.

Finally, we can employ statistical and numerical analyses to ensure that the actual data provided by the study participants corresponds with the feature surfaces, place attachment surfaces and summed surfaces produced. In this case, we are looking mainly for correlations to show that changes in outputs have the correct magnitude and direction, given the changes to the inputs. In this chapter, we are going to use statistical and non-statistical tools to provide evidence to validate the methods, software and results of the PAS. The goal is to demonstrate a chain of causality from the initial inputs to the results. This will be done using two approaches; the first will be to examine whether there is a direct correlation between the inputs provided by the participant and the results produced at each level of analysis (Figure 5.2). The second method will examine the correlation between one level of analysis and the next level. We expect that the first method will show reduced correlation values as we move from the inputs to higher and increasingly abstracted levels of analyses. The second method should show relatively consistent results, as error is introduced as we move to higher levels of analysis. Using the two methods helps us to be confident that the chain of causality is not broken, and that if a problem arises, we can identify where the problem occurs.

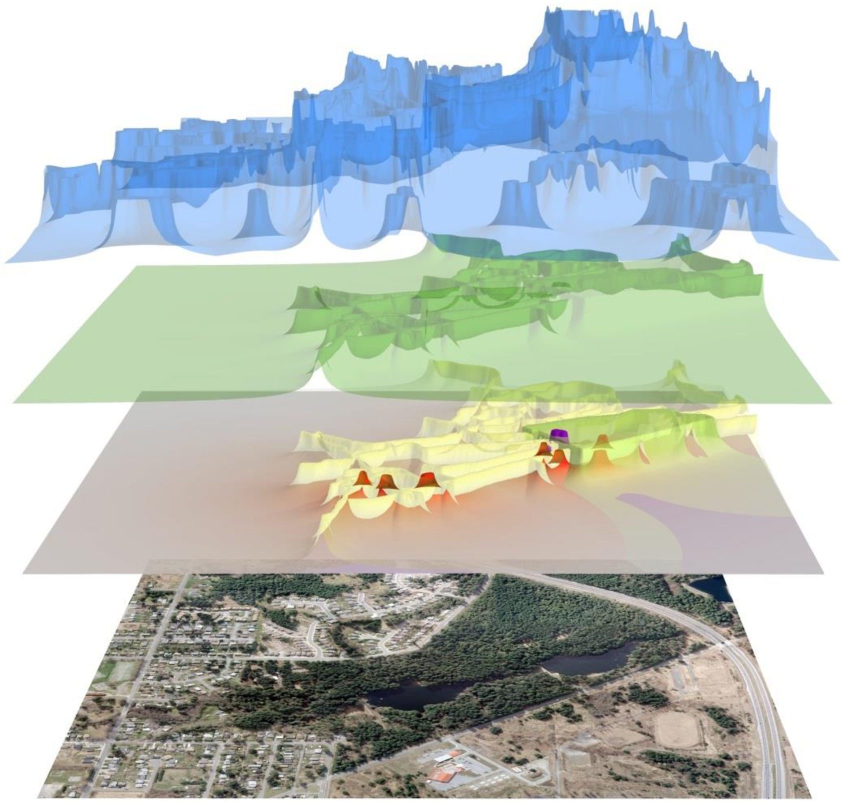


Figure 5.2. The three levels of analysis. In this example at the feature level, four feature surfaces are produced for Participant 014894177: trails (yellow), fishing areas (red), the swimming area (purple) and the dog off-leash area (lime green). These feature surfaces are combined together at the place attachment level to represent this participant's overall perception of the study area. At the summed level, the place attachment surfaces for the participants who came to walk their dog are combined to produce an overall surface. The between-level elevation differences are not absolute; levels have been separated for clarity. This view is from the north.

5.2 Testing Methods

The standard test for correlation is Pearson's product-moment correlation coefficient (Pearson's r). This parametric test has four assumptions, which are:

1. there is a random sample of paired variables;
2. the variables have a linear association;
3. the variables are measured at an interval or ratio scale; and
4. the variables are bivariate normally distributed (McGrew & Monroe, 2000, p. 198).

Using the data produced by this study, we have found that Assumption 4 was the most difficult to meet. Testing for bivariate normality is difficult, and independent tests of normality on each variable are often used in its place (Laerd Statistics, 2015). Thus, we made use of the Shapiro-Wilk test for normality on each of the variables in conjunction with an examination of scatterplots and Normal Q-Q plots to establish whether Pearson's r is the appropriate test for correlation.

If these assumptions are not met, it is possible to rely on the non-parametric Spearman rank-order correlation analysis (Spearman's correlation). Using Spearman's correlation instead of Pearson's r is relatively unimportant, because it has nearly the same statistical power as Pearson's r (McGrew & Monroe, 2000, p. 201). The assumptions for Spearman's correlation are much less limiting, allowing it to be used in a broader range of situations:

1. there is a random sample of paired variables;
2. the variables have a ***monotonically*** increasing or decreasing association; and
3. variables are measured at the ordinal scale or downgraded from interval/ratio to ordinal (McGrew & Monroe, 2000, p. 202).

The use of scatterplots is helpful to determine whether the variables have a monotonic relationship or whether a linear association is present (Pearson's r assumption 2).

Sometimes a correlation is masked by the effect of other variables; in such a case, we might make use of partial correlation to compensate. For example, the volume of a feature surface is roughly the product of its place attachment value and the square of the awareness distance specified by the participant. We initially wanted to determine whether there was a correlation between the volume of the feature surface and its place attachment value by eliminating the influence of the distance using partial correlation. The assumptions for partial correlation are strict, however:

1. there are independent and dependent variables, and both are measured at the interval or ratio scale;
2. there are one or more control variables measured at the interval or ratio scale;
3. there is a linear relationship between all variables;
4. there are no significant outliers in the data;
5. the variables are approximately normally distributed; and
6. bivariate normality is present for each pair of variables (Laerd Statistics, 2015).

Because of the many assumptions and the complexity of our data, we were unable to perform a multiple regression on our data.

In addition to the statistical methods used in this chapter, we used other, non-statistical checks. For example, for one test, we examined the difference between the sum of all place attachment values and the height of the summed surface.

5.3 Connecting Individual Features to Overall Perspectives

Before proceeding further, we need to assess the validity of our results. Although we can follow the logic through every step from the data collection to the production of place attachment surfaces, we need an independent assessment to determine whether the place attachment surfaces are a reflection of the input data. With the large amount of computer code involved, there is a possibility that a software bug might affect the production of the place attachment surfaces. The need for an independent test was anticipated during the survey design, so we asked each participant to provide an overall assessment of the importance of Colliery Dam Park.

Having a separate rating for the park allowed us to calculate an overall place attachment value, and compare it against the mean place attachment values for the individual features. The more important the overall park value, the larger the feature surfaces should be. If a correlation is present, it provides a method of assessing the quality of the PAS software.

For each participant, we calculated the mean of the feature surface pixel values (Ave_Feat_I) and the park place attachment pixel values (Feat_Impor). An examination of Shapiro-Wilk test results for Ave_Feat_I and Feat_Impor indicated that neither variable was distributed normally ($p < .0005$ in each case). For this reason, we chose the non-parametric Spearman rank correlation coefficient, which revealed a small correlation (Cohen, 1988), with $r_s(253) = .164$, $p = .009$. This result shows that the place attachment for the feature surfaces varies in step with the place attachment for the entire park. It does not prove conclusively that the place attachment surface is a good representation of the participant's understanding of the park, but it supports our assertion that there is a connection between how the participant views the park overall, and the place attachment surface that was generated from their inputs.

5.4 Data Analysis

The analysis of data in this chapter takes two forms: one is to compare the results at each of the three levels (feature surface, place attachment surface, and summed surface) with the source data from which they came, and the other is to compare the results at each of the three levels with the results at the previous level. All analyses conducted for this study use a 95% confidence level.

5.4.1 Comparison with Source Values

Comparing our results at each level of analysis with the initial responses of the participants helps to ensure the overall continuity of the analysis. This supports our argument that the results produced by the PAS are based on user inputs, and are not the product of design flaws or programming errors.

At the first level, we want to ensure that the dimensions of the feature surface correspond with the input place attachment values. The most obvious test is to compare the height of the feature surface with the input place attachment value; the height of the surface should be the same as the place attachment value.

To facilitate this analysis, a join was used to create table called Subsurface_Data was created that contained place attachment and morphometric data for the feature surfaces of each participant (*Input_Attachment*, *Actual_Attachment*, *Actual_Volume*, *Actual_Area2D*, *Actual_Area3D* and *Actual_Perimeter*). This was exported as a single table for analysis in SPSS 23 (IBM, 2016). To determine whether the height of the feature surface corresponds with its input place attachment value, we ran a correlation analysis between *Actual_Attachment* (the maximum height of the feature surface) and *Input_Attachment* (the place attachment value that was used to generate the surface). A scatterplot of these two variables is shown in Figure 5.3.

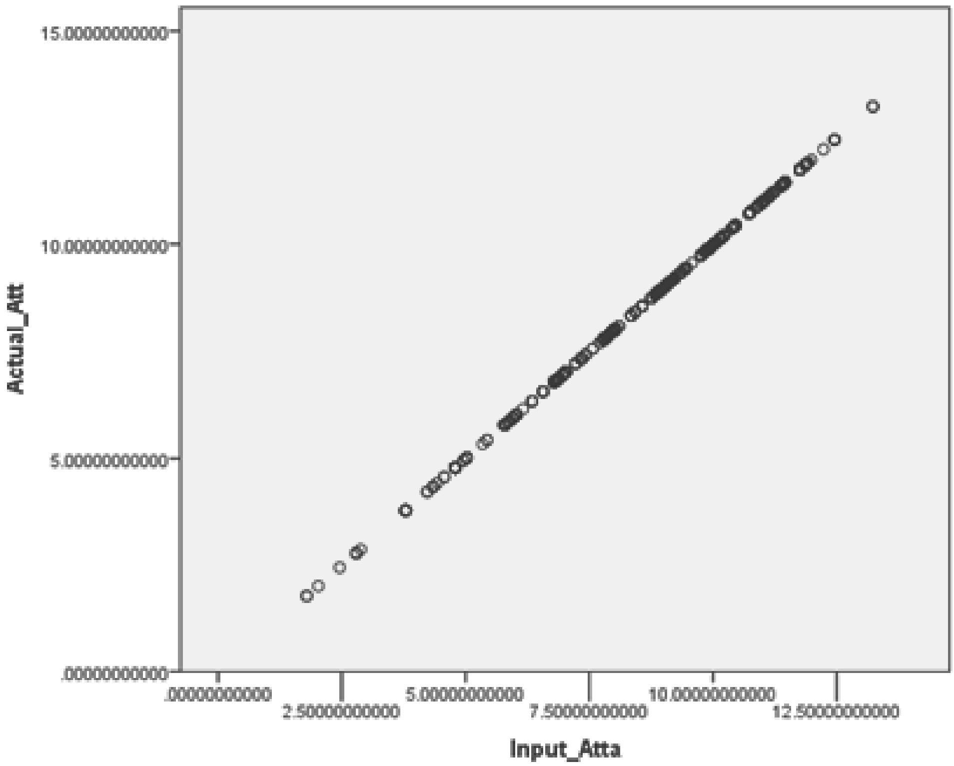


Figure 5.3. Scatterplot showing Actual_Attachment (Actual_Att) versus Input_Attachment (Input_Atta) (n = 881).

From Figure 5.3, it is apparent that there is a strong, linear correlation between the two variables. Although this is a random sample of paired variables and the variables are measured at the interval scale, we cannot use a parametric test of correlation (Pearson's r). The Shapiro-Wilk test of normality shows that neither value is normally distributed ($p <$ .0005 for both *Actual_Attachment* and *Input_Attachment*), so the assumptions behind Pearson's r are violated. A visual examination of the Normal Q-Q plot confirms that the distribution is not normal, with both variables having the same skewness (-.403) and kurtosis values (-.482). Therefore, Spearman's correlation analysis was run, as there was a monotonic relationship between the two variables, one of the assumptions for this test. A perfect correlation was found between *Actual_Attachment* and *Input_Attachment* ($r_s(879) = 1.000$, $p < .0005$). The number in parentheses (879) indicates the degrees of freedom.

Given that both *Actual_Attachment* and *Input_Attachment* are stored to 5 decimal places, it is not surprising that there is a perfect correlation shown between the two variables. Because Input_Attachment is used by the software to calculate the height of the feature surface, this analysis confirms that all data are being processed in the same manner. Nearly 95% of the observations had exact matches between *Actual_Attachment* and *Input_Attachment*, and the remaining observations were off by 0.00001, likely due to rounding error by the software.

The creation of each feature surface, although complex, appears to work correctly. Our analysis shows a perfect correlation between variations in the input and changes in the output, which suggests that there are no logical or software errors in this stage of data processing.

At the second level of processing, we want to determine whether there is a correlation between the place attachment surface and the input data provided by the participant. To determine this, we will take the maximum place attachment value for each participant from the *Mainform_Features* table, and will compare this with the volume of the place attachment surface that is generated. Higher maximum place attachment values should lead to higher place attachment surface volumes.

We first **Summarized** the *Mainform_Features* table (ESRI, 2017b) using the participant number to produce a summary table containing the maximum place attachment value for the feature surfaces created for each participant. This summary table was then joined to the *Parameters_Surface* table and exported to SPSS. The joined table contained the maximum of all place attachment values and the volume of the participant's place attachment surface.

Before checking for correlation, we examined the maximum place attachment value and the volume of the place attachment surface to determine whether each had a normal distribution. The Shapiro-Wilk test showed that neither had a normal distribution ($p < .0005$ in each case). A visual analysis of the Normal Q-Q plots for both variables exhibited negative skewness for *Max_Feat_I* (-.972) and negative kurtosis for *Volume* (-.642). Because of this non-normal distribution, we had to use non-parametric tests and make use of Spearman's correlation analysis. A scatterplot was run that displayed a monotonic relationship between maximum place attachment (*Max_Feat_I*) and Volume (*Volume*) as is shown in Figure 5.4.

Using Spearman's correlation, we found a medium correlation (Cohen, 1988) between the volume of the place attachment surface (*Volume*) and the maximum place attachment value (*Max_Feat_I*) for the feature surfaces ($r_s(237) = .331$, $p < .0005$). The medium correlation between *Volume* and *Max_Feat_I* may be because we are comparing a one-dimensional measurement (*Max_Feat_I*) to a three-dimensional measurement (*Volume*). Because of the complexity of the surfaces, taking the cube root of the volume is unlikely to reduce the complexity of the scatterplot significantly.

In addition, some feature surfaces occupy the same volume (Figure 5.5). If one surface is encased within another, then it is a subset of that surface (Zadeh, 1965) and does not affect the shape of the place attachment surface, because it is constructed with the Fuzzy OR

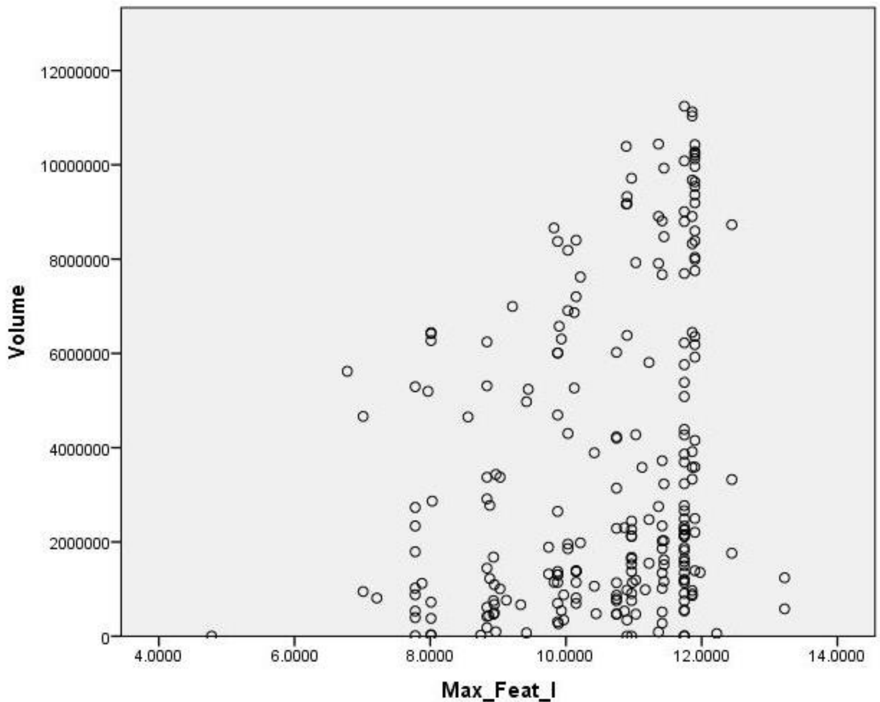


Figure 5.4. Scatterplot of volume (*Volume*) versus maximum place attachment (*Max_Feat_I*) (n = 239).

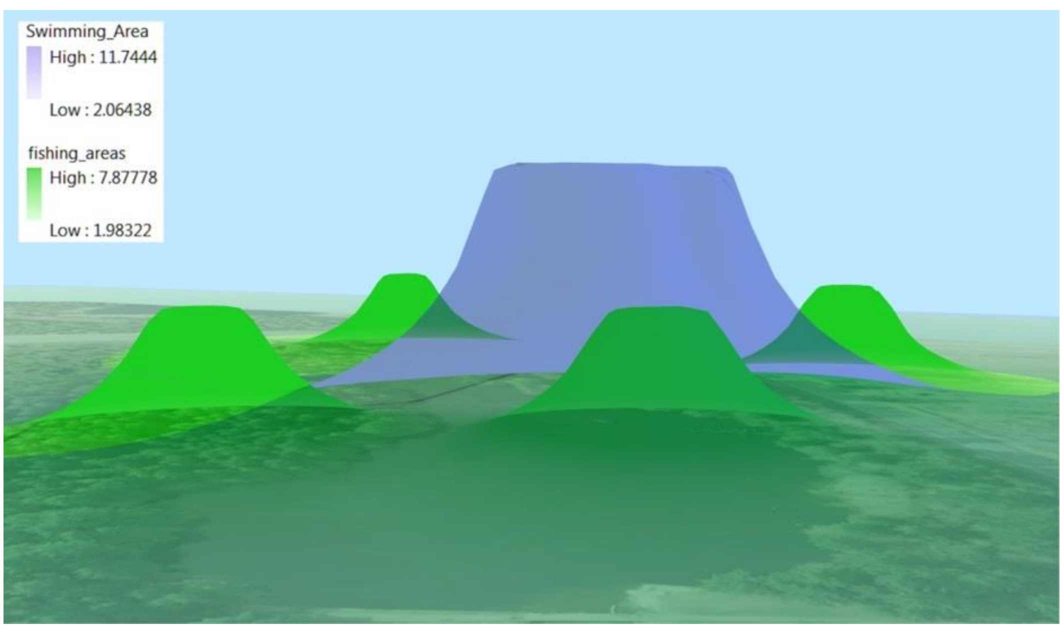


Figure 5.5. Feature surfaces with low place attachment values may be a subset of those nearby with high place attachment values. Here, we have four fishing areas (green) around the upper lake, which have a low place attachment for Participant 014894177. The closest of these is nearly coincident with the swimming area (blue) at the upper dam, which completely covers it. In this case, the feature surface for this fishing area does not contribute to the place attachment surface because it is encased by the swimming area. The image is viewed from the east and the vertical exaggeration is 5 times.

function. For example, if a feature with a high place attachment value exists near one with a low value, the decay surface of the first feature may overwhelm the second feature, even at the highest point in the second feature.

Obviously, the fishing areas were important enough for the participant to mention them in the survey. We interpret this to mean that although the participant is mainly focused on the importance of the swimming area; it does not imply that the participant is unable to consider the fishing areas (or any other features) in these areas. The place attachment surface simply

shows the maximum amount of place attachment present, not the feature on which a participant focuses at a particular moment in time.

At the third level, there is a summation of the place attachment values at each feature and a comparison of these values with the height of the summed surface at the same location. We expect that there should be a correlation present between the summed place attachment values and the overall height of the summed surface taken at each location. This analysis is quite involved, because the features identified by the participants may consist of many individual points, line segments or polygons. For each of these, it is necessary to sum the place attachment values at the exact location of each individual component.

To illustrate the difficulties of this approach, suppose that a participant identified "Waterfalls" as her feature, and its calculated place attachment value was 10.0. Each of the two waterfalls identified in the study area is mapped as a point; one is at the far western boundary of the study area and the other is near the center. If we calculated the ***centroid*** of the two points, it would fall exactly between the two waterfalls, and the value of 10.0 would be summed there, far from either waterfall. The solution is to examine each individual component; in this example, we would look at each of the waterfalls separately, and would sum the place attachment values for each separate component. Thus, for this participant, 10.0 would be added to the place attachment values of all participants who chose one waterfall, and 10.0 would be added to the place attachment values of a different group of participants at the other waterfall. In this way, we break down the features into their components, and compare the summed place attachment values for each component with the value of the summed surface at that location.

One further complication is caused by the shape of the line and polygon components themselves. When these are irregularly shaped, the centroid may not lie on the line or within the polygon. The feature to point command is used to calculate a ***constrained centroid*** (Figure 5.6). For each layer of data, this generated a corresponding layer of constrained centroids that were indexed by *Feature_ID*. Since the *Feature_ID* column has a unique value for each individual feature in the PAS, we could **Merge** (ESRI, 2017c) the centroid layers to create a single file called *All_Points*.

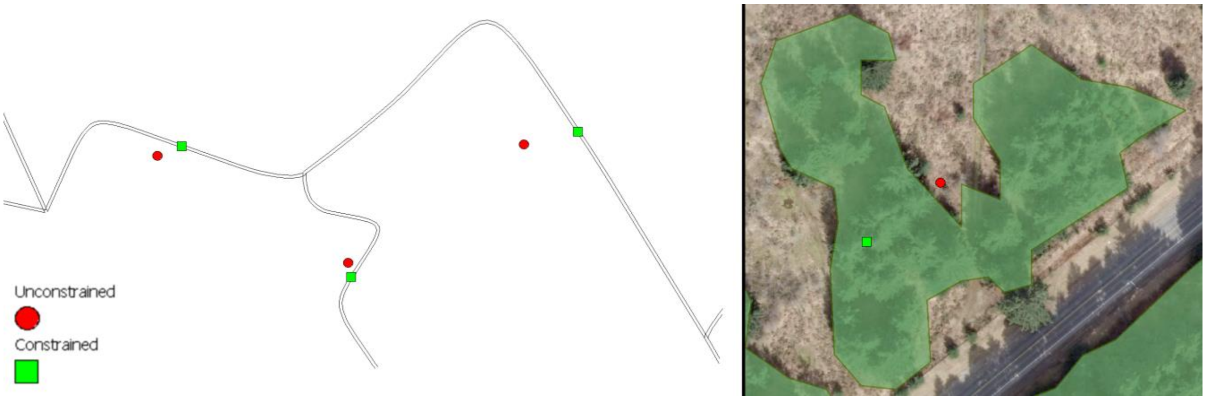


Figure 5.6. Constrained and unconstrained centroids for trail line segments (left) and forest polygons (right). For point features, the centroid is always at the exact position of the point, so there is no distinction between the two types of centroids. It is rare that centroids lie outside the polygon, except in cases such as this where the polygon is U-shaped.

The *Mainform_Features* table was joined to the *Mainform_Multiobject* table to create a complete list of all points, line segments and polygons that were used in the study. These were **Summarized** (ESRI, 2017b) on the *Feature_ID* column to create a sum of the place attachment values for each feature.

The *Mainform_Features* table was then joined to *All_Points*, using the matching *Feature_ID* column in each table. Since many of the features in *All_Points* were never mentioned by study participants, they had no match in *Mainform_Features*, and thus null records were returned. These null features were removed, and the resulting points were exported to a new layer of constrained centroids.

The **Extract Values to Points** command (ESRI, 2017d) was then used to obtain the value of each pixel in the summed surface, and to add this to the attribute table of the constrained centroids. In the resulting layer, this enabled us to compare the sum of all place attachment values (*Sum_Feat_I*) with the value of the summed surface (*Rastervalu*) at the position of the constrained centroid. *Sum_Feat_I* should be correlated with *Rastervalu* if the summed surface is a product of the input data (Figure 5.7).

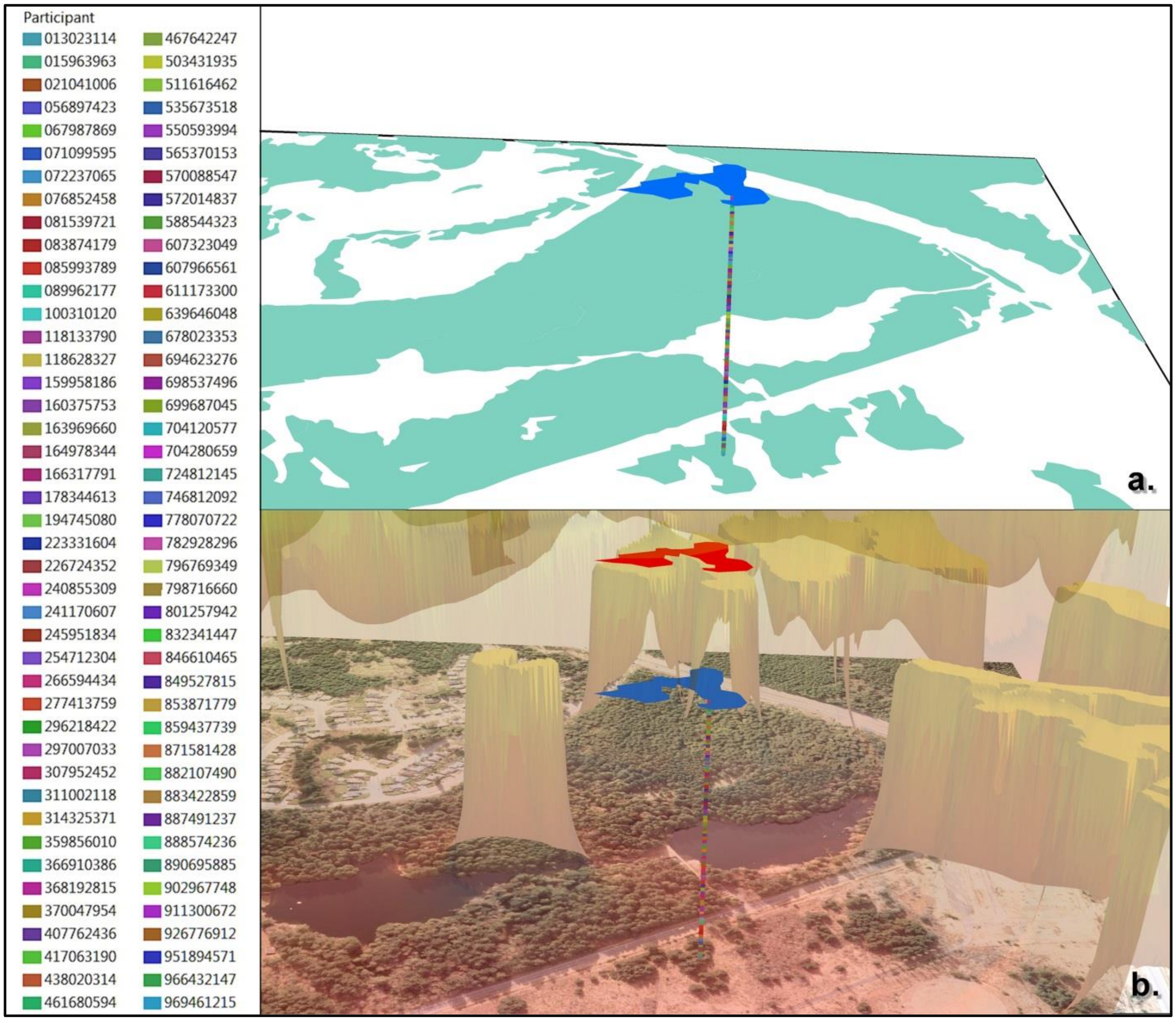


Figure 5.7. Calculation of expected summed surface height at constrained centroid for a polygon. Views are from the north. a. Eighty-six participants (shown by color) included this forested polygon in their list of important features; the vertical bar shows the contribution of each participant in numerical order from the ground upwards. The blue surface of the polygon has been elevated by the sum of all the place attachment values. b. Another view from the same perspective, with the semi-transparent summed surface added. The summed surface lies above the elevated polygon, at the position of the red polygon. The can be explained because the decay surfaces of the surrounding features also contribute to the height of the summed surface.

The summed place attachment for each constrained centroid (*Sum_Feat_I*) and the value from the summed raster (*Rastervalu*) were examined to determine whether they were normal. In both cases, the Shapiro-Wilk test confirmed that they were not normally distributed ($p <$ .0005). A visual inspection of the Normal Q-Q plots confirmed this, with *Sum_Feat_I* having high negative kurtosis (-1.265) and *Rastervalu* showing negative skewness (-.530). Pearson's r cannot be used with non-normal input variables to calculate the correlation between the two values. Thus a scatterplot was run to see whether the conditions of Spearman's correlation analysis were met (Figure 5.8). The requirement for a monotonic relationship between the variables has not been clearly violated, although the scatterplot results are difficult to interpret.

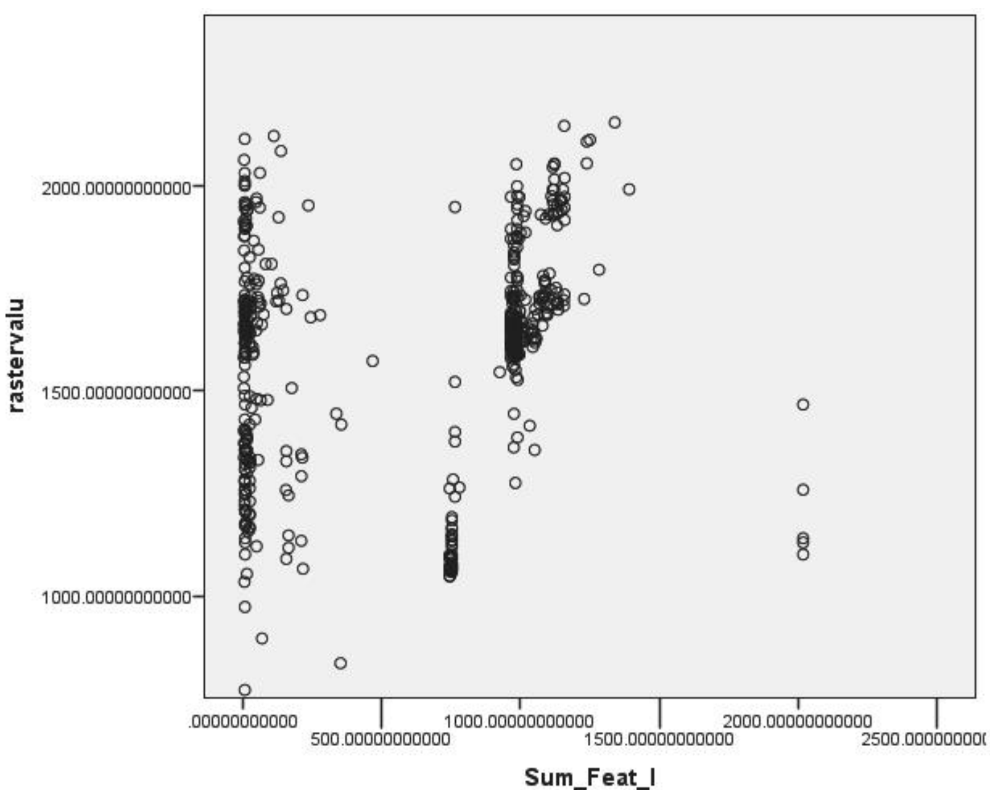


Figure 5.8. Scatterplot showing relationship between the summed place attachment values (*Sum_Feat_I*) and the value of the summed raster (*Rastervalu*) (n = 505).

Using Spearman's correlation, a moderate correlation (Cohen, 1988) was found between *Sum_Feat_I*, and *Rastervalu* (r_s(503) = .300, $p < .0005$). Although the scatterplot is inconclusive, the r_s value is not close to zero, which indicates that mathematically, the result is monotonic (Bhalia, 2017). The relatively weak r_s value is not surprising given that there have been three major data processing operations to arrive at the final summed surface.

5.4.2 Comparison with Values from Previous Levels

Comparison of statistics at one level of analysis with those from the previous level of analysis is another way of helping to validate that the data processing is consistent and makes sense. Comparisons between levels augment the statistics comparing each surface against the source data by providing more detail about where and in what way potential problems in the programming or design of the software occur.

At the first level, that of the feature surface, we can check for a correlation between the place attachment value for each feature and the volume of the feature surface. Higher place attachment values should be correlated with greater volumes for the feature surface.

Using the Shapiro-Wilk test of normality, we discovered that both the place attachment values (*Feat_Impor*) and the volume of the feature surfaces (*Actual_Vol*) lacked normal distributions ($p < .0005$ for both variables). The Normal Q-Q plots for *Feat_Impor* showed a pattern consistent with negative kurtosis (-.507), and the Normal Q-Q plot for *Actual_Vol* is far off the diagonal, indicating high skewness (2.628) and kurtosis (6.452).

An examination of the scatterplot for these two variables shows a monotonic relationship between the two variables, so the requirements of Spearman's correlation analysis have been met (Figure 5.9).

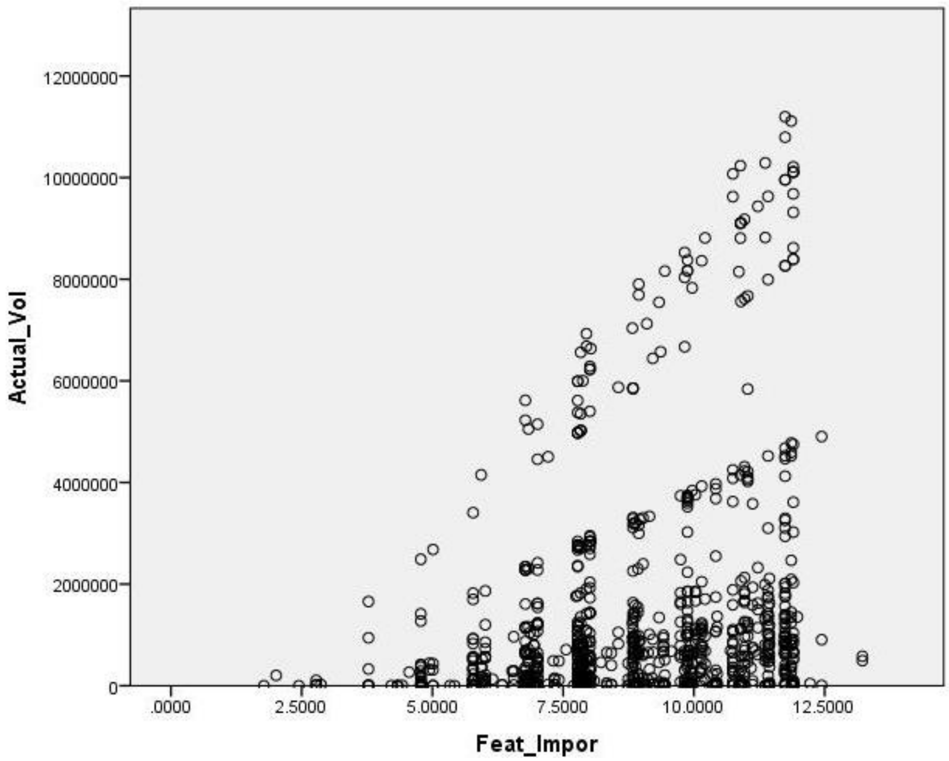


Figure 5.9. The correlation between the place attachment value given for each feature (*Feat_Impor*) and the volume of the feature surface (*Actual_Vol*) (n = 881).

Using Spearman's correlation, a medium correlation (Cohen, 1988) was found between *Actual_Vol*, the volume of the feature surface and *Feat_Impor*, the place attachment value ($r_s(879) = .317$, $p < .0005$). The correlation value makes sense given that we are comparing a one-dimensional value (*Feat_Impor*) with the index of a three-dimensional object (*Actual_Vol*).[4]

[4] We also ran a partial correlation, adding in the square of the awareness distance as a controlling variable, but the best resulting correlation values were the same as for Spearman's correlation analysis. Given the data

At the second level of processing, the creation of the place attachment surface, we wanted to establish whether the parameters of the place attachment surface reflected the feature surfaces that were used to generate it. To do this, we looked for a correlation between the feature surface volumes and the place attachment surface volumes. This helped to determine whether the move to this level had been applied consistently for all study participants. Because we were comparing volumes against volumes, we expected the correlation to be high, because the dimensionality of the measures is the same.

The *Subsurface_Data* table was used as a source of data. The **Summarize** command (ESRI, 2017b) calculated the sum of the feature surface volumes for each study participant and generate a new table. The result was joined to *Parameters_Surface* so that we could examine the differences between volumes at the feature surface and place attachment surface levels.

We then ran the Shapiro-Wilk test and examined descriptive statistics to see if both variables were normally distributed. Descriptive statistics for the *Sum_Actual* variable indicated a high positive skewness value (.984) and a low kurtosis value (.001); the same pattern was observed for *Volume* (skewness = .834, kurtosis = -.642). The Shapiro-Wilk p value was less than .0005 in both cases, confirming that the variables were not normally distributed. For this reason, we were unable to use Pearson's r, so we checked to see whether the assumptions of the Spearman correlation analysis were met.

transformations required and the difficulty of meeting the assumptions for this test, it makes sense to report the simpler Spearman's values.

A scatterplot between *Sum_Actual* and *Volume* was created to determine whether there was a monotonic relationship between the two variables. The scatterplot seems to indicate that this assumption is not violated (Figure 5.10).

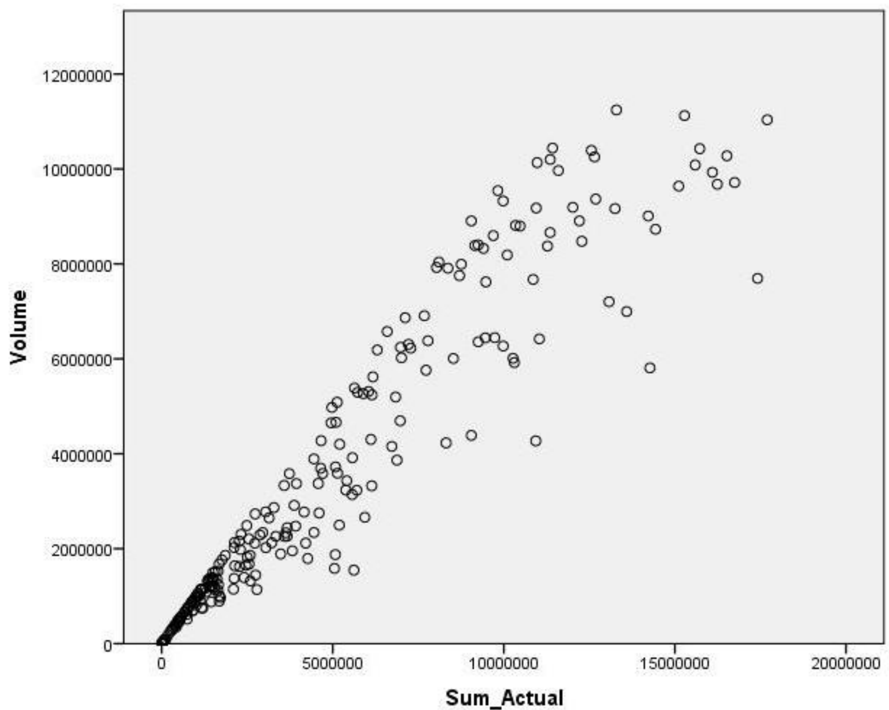


Figure 5.10. Scatterplot of summed volumes for feature surfaces (*Sum_Actual*) versus total volume for the place attachment surface (*Volume*) (n = 239).

According to Spearman's correlation analysis, there is a strong correlation between the sum of the feature surface volumes (*Sum_Actual*) and the volume of the place attachment surface (Volume) ($r_s(237) = .977$, $p < .0005$).

At the third level, a comparison of the summed volumes of the place attachment surfaces and the volume of the summed surface will help to show whether there has been an error at this level of analysis. Examining the relationship between the place attachment surfaces and the summed surface does not require correlation analysis; we can simply sum the volumes of the place attachment surfaces, and this should equal the volume of the summed surface.

The *Parameters_Surface* table was used for this analysis. To calculate the total volume of the place attachment surfaces from the table, we need to select the valid participants and sum the *Volume* column. To get the volume of the summed surface, the **Surface Volume** command (ESRI, 2017e) was employed.

The total volume of the place attachment surfaces was 1,696,884,507 m^2A (meters squared × place attachment), according to the statistics command. The volume for the summed surface was 1,696,884,827 m^2A, a difference of 0.00002%.

5.5 Correlations Found

At the feature surface level, there is a medium correlation when we compare our results with the source data using volumes and a perfect correlation when we compare the results with the source data using maximum height of the feature surface. When comparing the height and the volume of the feature surface against the place attachment values, there is evidence that the feature surfaces produced by the PAS are consistent, and reflect what we expect to see.

At the place attachment surface level, the first analysis produces a medium correlation (Cohen, 1988), since it is advancing two steps from the raw input data, and the second produces a strong correlation, because it is only advancing a single step to the feature surfaces. In both cases, the results are consistent with what we expect if the software is doing its job properly.

At the summed surface level, we once again see a medium correlation between the summed place attachment values for each participant's point, line or polygon features and the height of the summed surface. When comparing the place attachment surfaces against the summed surface at the next level, we have nearly an exact match, with only a 0.00002% difference between the values.

Overall, the results at each level are good, and reflect what is expected given the depth of data analysis in this project. Table 5.1 summarizes the findings for each level and type of comparison.

Analysis Level	**Comparison with Source Data**	**Comparison with Previous Level**
Feature Surface	$r_s(879) = .317$, $p < .0005$	$r_s(879) = 1.000$, $p < .0005$
Place Attachment Surface	$r_s(237) = .331$, $p < .0005$	$r_s(237) = .977$, $p < .0005$
Summed Surface	$r_s(498) = .327$, $p < .0005$	0.00002% difference (n = 239)

Table 5.1. Summary of tests at each level of analysis, both compared with the initial data provided by the participants, and compared with the previous level.

Surprisingly, the comparison with the source data did not decline steadily as expected, remaining more or less constant. Each successive level of analysis should be more abstracted from the original data than the previous layer. Moving from the feature surface level to the place attachment surface level, the r_s value actually increased slightly from .317 to .331. This minor increase in the r_s value may simply be a product of how the tests were formulated.

The comparisons with the previous level were consistently strong throughout the analysis. For the final, non-statistical analysis at the summed surface, the 0.00002% difference between the volume of the summed surfaces and the sum of the place attachment surface volumes is particularly strong.

The comparisons with the source data show that there is a consistent correlation at each analysis level, and the correlations between levels are very strong. This supports our contention that the software is working as expected, and that the software is not introducing significant amounts of error into the process as we move from feature to place attachment to summed surfaces. If it were, we would expect to see a sudden decline or increase in the Spearman correlation coefficient as we move from one level to the next.

5.6 Significance of Correlations

We have shown that there is a connection between each participant's assessment of features in the park and their assessment of the park, overall. In addition, we have demonstrated that there is a chain of causality from the raw data to the summed surfaces. This chain has been shown between each level of analysis and between the input data provided by the study participants, and each successive data product.

We have been thorough with our analysis and the requirements for each test, and given the statistics, we can be quite certain of the correlation values and the results presented. However, it is important to remember that at our 95% confidence level, there is still a 5% chance of a Type I error for each test, where the correlation is simply the result of chance.

Fortunately, in this case, the "theory" is software that was designed from the ground up, and which has been tested extensively. Although the techniques used in this chapter cannot conclusively prove that the software works, we understand how the connections between analysis levels were created, and so the correlations and comparisons shown provide strong, independent support that the software behaves as designed, and produces consistent results. The analyses shown in this chapter support the methods used, and encourage their further development and refinement.

Statistical analysis is only one of several different kinds of analysis, such as those discussed in Section 5.1, which can provide evidence that the PAS is effective. These other types of analyses can provide further lines of support to ensure that the development of the PAS remains on track. These will be explored in the near future to continue building support for the methods and software used in the PAS.

Chapter 6: Application 1: Planning Tool

> Geographers have long been exercised by the problem of defining regions, and this question of 'definition' has almost always been reduced to the issue of drawing lines around a place… (Massey, 1997, p. 320).

In previous chapters, we introduced a new method for mapping and representing places and we demonstrated that there was a chain of causality from the input data provided to the final summed surfaces produced for all participants. Given that there is a firm foundation for the results that the PAS has generated, it is time to explore the applications of these data.

With increasing demands from the public for openness and transparency in government, it is more important than ever to demonstrate that planning decisions are made on a rational, impartial and transparent basis. Public decisions should reflect the best interests of the public and taxpayers, and should ideally be free of the influence of power and money. Understanding place attachment requires that public consultation be conducted before a planning exercise begins and demonstrates a commitment to openness and transparency. Having such information gives park planners the ability to identify areas where changes are likely to be opposed by members of the public, *before* plans are even started.

Building on the concept of place attachment allows for the construction of planning tools that can make planning easier, more efficient and less costly than current methods. Being able to determine place attachment over the entire study area for all participants yields new insights into the importance of place, not only for the park as a whole, but also for subsections of the park. In the case of Colliery Dam Park, all areas within the park boundary have medium or high place attachment values, but some areas immediately outside the park boundary also have medium to high values. It would be quite easy for the City of Nanaimo to expand the park to include the adjoining city-owned lot to the south, as the only change required would be the legal designation. However, there is an opportunity cost if this lot cannot be sold for housing development because it has been formally designated as parkland.

In this chapter, we apply the PAS to solve a challenge that has the potential to become highly politicized. To the south and west of Colliery Dam Park, a number of city lots are being considered for addition to the park. Recent political events, such as the proposed deconstruction of the two artificial dams that hold back the lakes in Colliery Dam Park (Gorman, 2012) have left the public highly vigilant and suspicious of city motives. Ensuring that the disposition of the city-owned lands adjoining the park is done responsibly is thus very important at this time. We will analyze the options for increasing the size of the park using the PAS, but we will also examine whether all of the lands need to be used for this purpose, or whether it makes sense to allocate a portion of the city-owned lands for residential development. Using summed place attachment surfaces for this purpose will help to ensure that such decisions are made in a manner that is sensitive to the opinion of park users.

6.1 Expansion of Colliery Dam Park

The study area extends beyond the boundaries of Colliery Dam Park and includes many parcels of different zoning types (Figure 6.1). City planners are considering an expansion of the park, which would add as many as three city-owned lots, increasing the size of the park nearly fivefold (Personal Communication, Kirsty MacDonald, Parks and Open Space

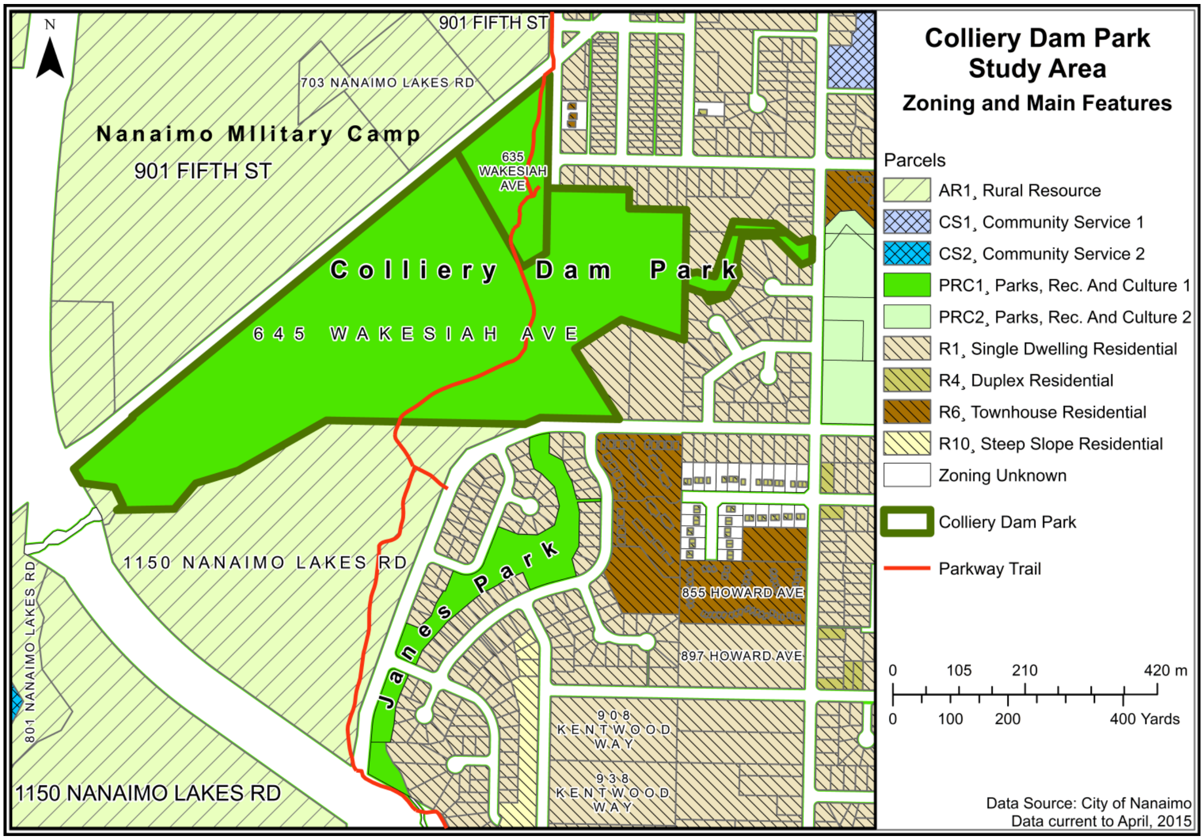


Figure 6.1. Zoning, main features and parcels within the study area surrounding Colliery Dam Park.

Planner, City of Nanaimo, Nov. 4, 2014). Figure 6.2 shows that only part of the proposed expansion parcels lie within our study area.

Part or all of these proposed expansion parcels may be allocated as parkland; it may be pragmatic to subdivide the expansion lots, allocating part to residential development and part to parkland, depending on the importance of different areas. This may be a way for the City to make the amenities in an expanded park revenue-neutral. As Nanaimo's population and land values increase, it is critical that such areas be considered for formal addition to the park, otherwise places of significant public importance may be destroyed by encroaching residential development.

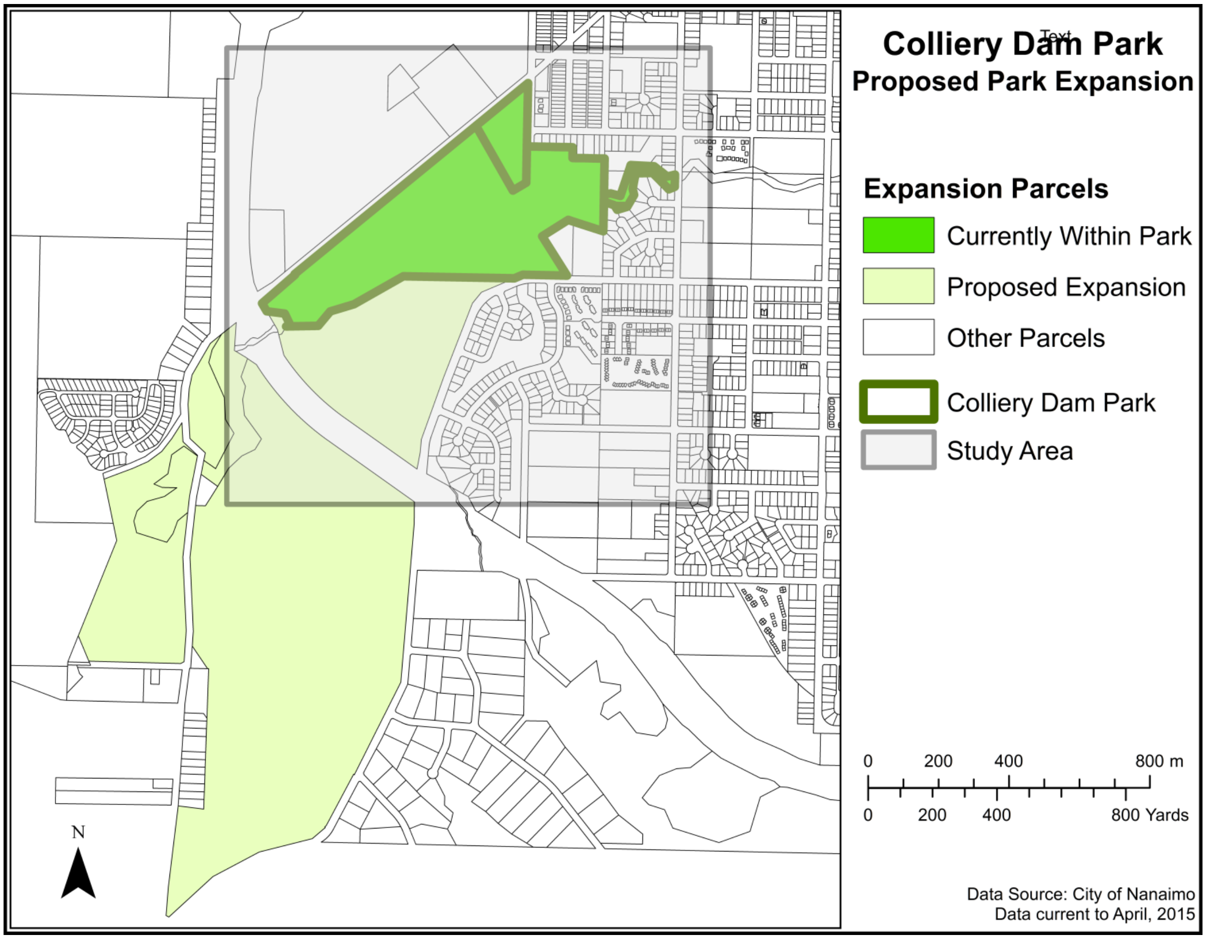


Figure 6.2. Proposed Colliery Dam Park Expansion (Personal Communication, Kirsty MacDonald, Parks and Open Space Planner, City of Nanaimo, Nov. 4, 2014). See Table 6.1 and Table 6.2 for a summary of the areas involved.

The Parkway Trail connects the park with 1150 Nanaimo Lakes Road, one of the lots being considered for expansion. Because the boundary of this lot is not marked, most park users assume that it belongs to the park; many study participants included features from this lot in their survey responses, even though they were asked specifically about features within Colliery Dam Park (see Chapter 3). From this, we can see that the proposed expansion of the park would bring the park boundary more into line with public perceptions.

The following two tables summarize the lot parameters and the status of the expansion lots relative to the study area. Table 6.1 shows the current lots in the park and the expansion lots being considered; Table 6.2 shows the breakdown of the existing and proposed expansion lots within and outside the existing study area.

Current Park Lots		**Proposed Expansion Lots**	
645 Wakesiah Ave.	24.7 ha	1150 Nanaimo Lakes Rd.	81.4 ha
635 Wakesiah Ave.	2.5 ha	801 Nanaimo Lakes Rd.	5.5 ha
739 Howard Ave.	0.7 ha	1151 Nanaimo Lakes Rd.	11.9 ha
Total	**27.9 ha**	**Total**	**98.8 ha**

Table 6.1. Current and proposed expansion lots for Colliery Dam Park. Note that there is no requirement for any expansion lot to be included in whole or in part.

Zone	Lot Address	Area Within Study Area (ha)	Area Outside Study Area (ha)	Percentage Within Study Area	Percentage Outside Study Area
Current Park Lots	635 Wakesiah Avenue	2.53	0.00	100.00%	0.00%
	645 Wakesiah Avenue	24.68	0.00	100.00%	0.00%
	739 Howard Avenue	0.75	0.00	100.00%	0.00%
Proposed Expansion Lots	801 Nanaimo Lakes Road	2.14	3.39	38.70%	61.30%
	1150 Nanaimo Lakes Road	26.88	54.53	33.02%	66.98%
	1151 Nanaimo Lakes Road	0.07	14.45	0.05%	99.50%

Table 6.2. Areas and percentages of current and proposed expansion lots for Colliery Dam Park.

6.2 Planning of Places

Relph points out that traditional planning often ignores the importance of place: "…much planning and remaking of landscapes proceeds apparently in ignorance of the importance of place, even though the protests of the expropriated and uprooted demonstrate this very importance" (Relph, 1976, p. i). The risk of such a blind approach to development is that a place may be destroyed because of accidental or willful inattention to place attachment and its cognitive and affective components. As Xu states: "Planning solutions... must be responsive to the people on whose life [sic] they have impacts" (Xu, 1995, p. 97).

Fitchen describes the changes to place identity that result as a place is progressively altered: "…once developed, a place identity is maintained only as long as it is plausible. It can become implausible if changing conditions make it inadequate for its primary purpose.

Holding on to one's place meanings may become increasingly challenging as the gap widens between the meaning and the physical characteristics of the setting" (Fitchen, 1991 as cited in Steadman, 2003).

Planning has undergone a transition from a technocratic, expert driven profession to one in which there is a great deal of public involvement. However, it is still uncertain whether public involvement can be incorporated properly into final designs. The volume of information is daunting, and this calls for a methodical approach to collecting, processing and analyzing the information that the public provides.

Faga states "…experience proves that it's much more effective to initiate a proactive process to involve the public. That's not to say it's easy, just that it works better and produces better results in the long run" (Faga, 2006, p. 156). Local residents often have knowledge gained through years of situated experience that professionals lack, but the professional skills and knowledge of the planner are also critical. Working together, the public is able to identify problems whereas the planner has the means to solve them, which results in more solid, well thought-out plans (Sanoff, 2000).

Not only does public involvement lead to better outcomes, but it can also be argued that a process that incorporates public input has greater legitimacy. Bengston *et al.* put it bluntly: "Policymaking for natural resources issues is a political process, and public participation is required if those policies are to have legitimacy" (Bengston *et al.*, 2004, as cited in Lowery & Morse, 2012). The validity of a plan can be judged by the degree to which it benefits citizens and the degree to which it is based on the opinions of the people it affects. If a planner gets a design right, then it may work spectacularly, but if wrong, the design may be met by an intransigent public or it may be discredited entirely, which may result in its redesign or abandonment.

Today, public processes involve 90% collaboration with the public and 10% presentation of information (Faga, 2006). The key to making such a process work is to design questions for public consumption, and to employ a skilled facilitator, who is able to keep discussions on track. In a climate of mediated, respectful dialogue, people may change their opinions in light of new information, thus reducing the "them and us" dynamic (Sanoff, 2000). The trend towards increasing public participation in both GIS and planning have brought them together, such that GIS can provide meaningful inputs for planning through the use of sophisticated and appropriate models of public perception.

Planning has had struggles with democratic decision-making processes. Rarely does the public speak with a united voice, and attempting to reconcile different viewpoints can be difficult (Sanoff, 2000). Aitken and Michel explain the problem this way:

> ...lack of consensus often occurs when participants are more concerned with disclosing their political identities and agendas and seeking results that support these, rather than with working to obtain a mutual understanding among all parties involved (Aitken and Michel, 1995, p. 23).

Often people and groups with vested interests dominate public hearings, charrettes and open houses:

> Public involvement in the planning system is often perceived as a 'them and us' situation with authoritative decisionmakers having exclusive access to knowledge, expertise and power. Other participants in the process are primarily large organisations or pressure groups with vested interests, as opposed to individuals or small community groups. This can often lead to the vocal minority dominating the debate at the expense of the general population (Carver, Evans, Kingston and Turton, 2001).

Even individuals who attend planning functions are self-selecting and, thus, do not fully represent all viewpoints. Those with greater education have a disproportionate influence over planning exercises (Appleton and Lovett, 2005), and the reverse is true for young people (Dennis, 2006). Thus, the aim of planners is often to control the agenda (Dennis, 2006), attempting to balance competing interests.

Given the exigencies of preparing a plan on time and on budget, it is not surprising that a straight-line route is often taken. Creating a plan with limited public involvement, and later asking for approval at highly controlled meetings has distinct tactical advantages. However, it is often evident to the public that genuine opportunities for input are limited, and this puts the planner in the position of having to defend the plan that is being presented (Cullingworth & Nadin, 2002, as cited in Appleton & Lovett, 2005).

Appleton and Lovett point out that the map is a tool that has the ability to transcend educational differences and, thus, can be important in receiving and providing information to the public. If maps are therefore such a powerful tool, why is GIS not employed in planning more frequently?

Considering that one of the early places where GIS was developed was the Harvard University Graduate School of Design (Chrisman, 2006), it is surprising that GIS and planning are not integrated better. Batty (2013) points out that "To an extent, GIS emerged as a systematic response to exploring conflicts and differences between different characterizations of landscape…." GIS and Planning diverged in the 1970's, for both epistemological and technological reasons. Taylor has pointed out that it is difficult to make use of GIS for modeling "…complex phenomena, like soil, terrain, or urban landscapes, or of geographical knowledge and understanding" (Taylor, 1990, p. 36). Planning tends to be a shared activity; and until recently, the technology of GIS made it a solitary activity (Batty, 2013). GIS data entry and processing formed a "bottleneck" that did not integrate well with the rapid-fire activities of planning.

For many years, researchers have posited that Geographic Information Systems (GIS) are not completely compatible with the goals and needs of the planning profession (Batty, 1992; Couclelis, 1991; Goodchild, 1992; Hanna & Culpepper, 1998; Sheppard, 1995). In spite of this, some efforts have been made to use GIS in the planning process (Hanna & Culpepper, 1998), with differing degrees of success. GIS can be used for planning in three modes. These are:

1. using GIS to provide valuable inputs to the planner, which would not otherwise be available;
2. using GIS to provide foundational data on which a planner may build; and
3. performing planning within a GIS-based framework.

In the first mode, planners provide the questions and GIS provides the answers. The strengths of GIS for modeling and visualization are made available to the planner, who then integrates these different inputs into a cohesive plan. Many planners feel that advanced, application-specific GIS functions should play a role in the preparation of urban and regional plans (Batty, 1992; Couclelis, 1991; Sheppard, 1995; Webster, 1993). Hanna and Culpepper (1998) point out that slope maps, suitability models, capability models, and predictive models have much to offer the planner. GIS-based planning support software such as CommunityViz (City Explained, Inc, 2017), and What if? (Klosterman, 2017) are now available to provide inputs of this type. The problem with this approach is that the planner is in charge of the process, and may not be fully aware of what new things GIS can offer to planners, leading to its underutilization. Until more planners become aware of what GIS can do, this approach will proceed slowly.

In the second mode, GIS provides a scientific foundation on which planning activities may be performed. The PAS may operate in this mode to provide useable information on place attachment. Planning is a dynamic, spontaneous activity, which is somewhat at odds with the deliberative and rigid nature of traditional GIS. Because GIS has a steep learning curve and is constantly changing, keeping abreast of the technologies is a full-time position; it is not simply a skill set that a planner can "tack on" to their existing skills. Hanna and Culpepper (1998) point out that many planners are artistic in nature, and feel constrained by the tools offered to them in GIS. In short, there is "no Zen in computers" (Hanna & Culpepper, 1998, p. 92). The volume of data that is stored and can be generated through GIS analysis can be overwhelming, and may feel constraining to planners who are more accustomed to beginning with the *tabula rasa*, rather than a map that is already filled with buildings, historical artifacts and people's sense of place. In other words, it is easier to plan if we deliberately select a limited set of aspects of place to retain (that is, a caricature), rather than to deal with place in all its complex, contradictory glory.

In the ethnos concept of place (Williams, 2014), places are valued for their ability to withstand time, their cultural value, and their "authenticity." Augé (1992) takes issue with places that lack authenticity, such as shopping malls, airports and freeways. Only with a limited concept of the nature of a place can a planner set out to perform "place making," a concept that is absurd when we consider the incredible depth and nuances present in places that are important to people.

In the third mode, GIS, planning, and other geomatics-related activities are used together, with GIS providing for integration of the activities. Because the technology of GIS is constantly improving (Sester, Bernard & Paelke, 2009), it is increasingly possible to perform planning within a GIS. It has taken decades of work to bring GIS from its infancy into mainstream use, and only in the past few years has an effort been made to integrate planning into a larger framework, led primarily by the Environmental Systems Research Institute (ESRI) through their ***GeoDesign*** initiative (http://www.esri.com/events/geodesign-summit).

Batty (2013) sees the development of GeoDesign as being the result of four factors coalescing. These are:

1. GIS tools have matured sufficiently to support planning activities.
2. Multiple designers can now work on a project at one time. This has been enabled by the development of geodatabases, which allow simultaneous edits without conflicts, as well as the development of web-based and cloud-based GIS, which extend the ability to edit GIS databases simultaneously and make them available worldwide.
3. Planning is going through a phase of technological innovation, of which GIS is but one part.
4. Both planning and GIS have been reformed from "top-down" to "bottom-up" activities. Both professions were formerly positivist, elitist and technocratic, and both have since moved towards being post-positivist and public-oriented.

One new development that is gaining acceptance is spatiotemporal GIS, which promises to enable new modes of operation in planning when planning and GIS are used together in GeoDesign (Batty, 2013). In addition, over the past two decades, spatial data has gone from being a rarity to being commonplace; and while the applicability of spatial data for particular purposes should be questioned (Aitken & Michel, 1995), it is now easy to acquire spatial data for planning activities.

It is important to acknowledge that GeoDesign represents neither a takeover of planning by GIS nor an abandonment of GIS technology, but rather a symbiotic combination of the two based on shared foundations and new technological capabilities. Both disciplines are undergoing rapid technological change, and for GeoDesign to succeed, the planning profession must embrace new ways of looking at places, whereas the GIS community must pay careful attention to how planning, as a creative activity, is performed. Once GIS tools are accepted by the "early adopters" in the planning profession, then the GIS community can take the lead to refine these methods.

6.2.1 Places on Maps

Geography examines the patterns of activities in space, and increasingly in time. One of its main tools is the map, which gives geographers a different viewpoint from other disciplines; being able to examine a scenario holistically from above, in addition to incorporating the same statistical methods employed in many other disciplines. This viewpoint assists us in understanding the spatial relationship between objects. James (1954, as cited in Relph, 1976) states: “Geography is concerned with the association of things that give character to particular places.” Taking the overall view, rather than examining individual spatial relationships, gives us the concept of *landscape*. Sauer (1963, as cited in Relph, 1976) explains that this landscape view is inextricably linked with the work of geographers: “The facts of geography are place facts: their association gives rise to the concept of landscape.” In this study, we are examining a psychological landscape, which, although invisible, can be made visible and operationalized through spatial analysis in a GIS.

One of the issues with previous studies of place attachment is that the extent and degree of place attachment has not been mapped accurately. As discussed in Chapter 3, the PAS allows the exact location and strength of place attachment to be mapped for the first time. The result is a place attachment surface representing the view of a single study participant or a summed surface representing the combined views of many participants. The summed surfaces show a communal understanding of place, and have some similarities to mental maps, but are georegistered so that we can exactly identify the areas with high place attachment, as well as those that have low place attachment or are unknown to participants. The geolocation of these surfaces means that the results are compatible with other map-based activities such as planning.

Colliery Dam Park has subjective boundaries because of the presence of many of the factors described by Couclelis (1996). The park is inhomogeneous (Figure 6.3), multi-dimensional, has use patterns that vary by season, and is defined by its users. People move into and out of the park effortlessly, often without being aware of it. Furthermore, people's conceptions of the park extend beyond the legal boundaries and the study area (Chapter 4). The subjective park boundaries can be defined from the summed place attachment surfaces, and represent a democratic definition of place.

6.2.2 Place-Based Planning

Lowery and Morse (2012) have coined the term "Place-Based Planning" to describe planning that is conducted with features tied to their real world coordinates, which makes it easy to use them as inputs for GIS analysis, as well as making them available for comparison with the outputs of GIS analysis and modeling. Bengston *et al.* point out "Increasingly, it is important

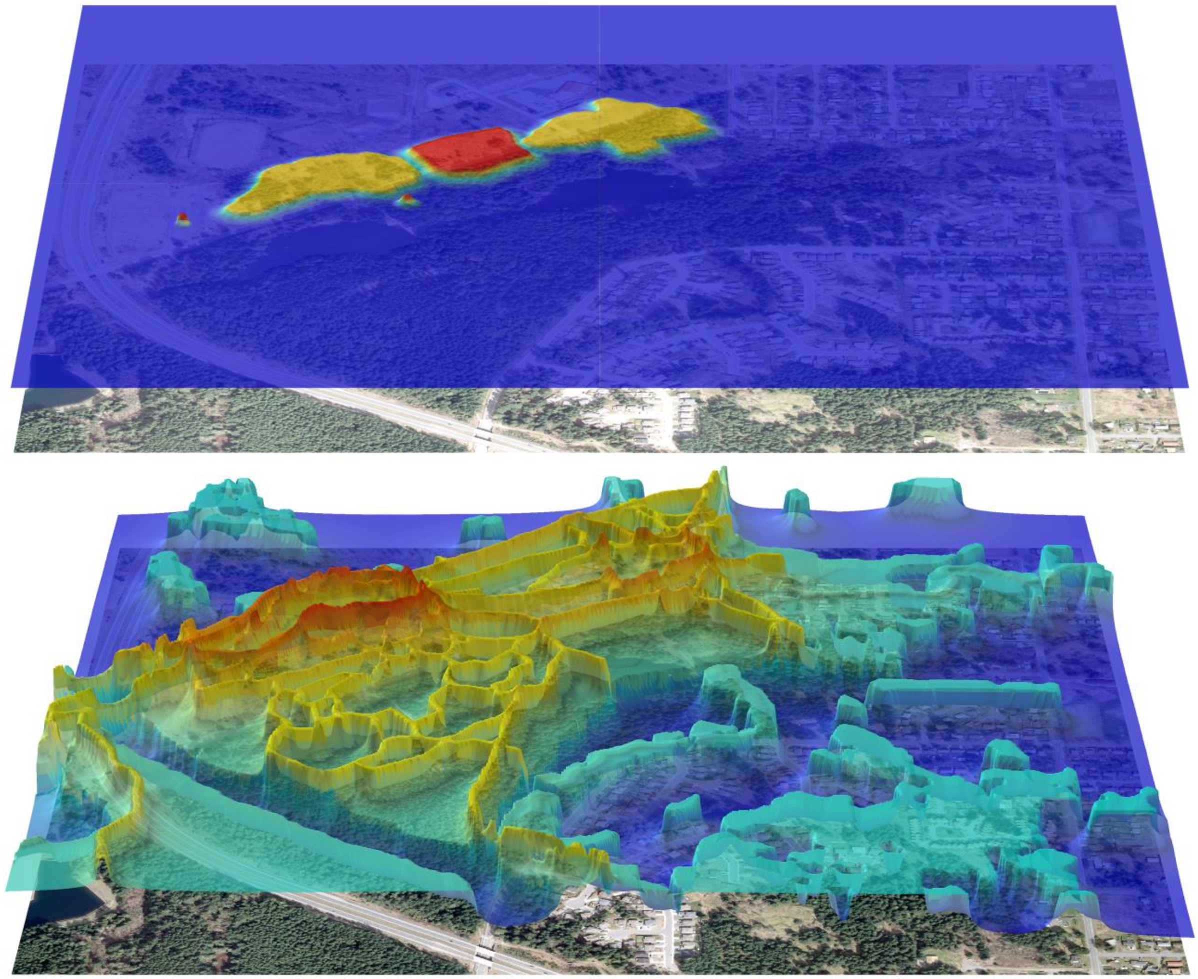


Figure 6.3. A single place attachment surface on top (vertical exaggeration 10x) and the summed surface for 239 participants on the bottom (vertical exaggeration 0.1x), both shown above an orthophoto of the study area. Note that neither boundary falls to zero (the level of the orthophoto), and that the summed surface on the bottom is very complex, and possibly fractal in nature.

to understand these public perspectives in a spatial format (place boundaries) because much of natural resources management is done in a spatial context (Bengston *et al.* 2004, as cited in Lowery & Morse, 2012).

It is important to ensure that the information recorded by the public is therefore tied to the *correct location* on the Earth's surface. Given the fading of memory over time, it is unlikely that a survey asking the public about specific locations long after they have visited would be accurate. Subjective boundaries, although collected from study participants, are tied to real-world features, which are mapped using a Cartesian coordinate system. This allows them to be converted to artificial boundaries on the same map if needed. This important compromise allows most of the information collected for cognitive mapping studies to be used with GIS and planning tools. Brown and Raymond (2007) point out that "The ability to identify and map landscape values and special places is viewed as an operational bridge between sense of place and place attachment" (p. 92).

By asking participants about their assessment of previously geolocated features, we can ensure that the perceptions of one participant can be meaningfully compared with the perceptions of another. We can analyze the surfaces to highlight the areas of common interest, and explore where the place attachment surfaces are different. This opens up opportunities for the exploration of why place attachment surfaces are different, something that is simply not possible unless we begin with geolocated features.

Brown (2006) reinforces how geolocated data collected during public participation activities can be used in planning:

> By asking residents to map landscape values and places perceived to be appropriate and inappropriate for both residential and tourism development, the relationships between perceived landscape values and resident development preferences can be made explicit. Further, maps can be generated from the spatial data that show areas of resident agreement or disagreement regarding future development…. These maps can be overlaid with existing zoning plans to assess the consistency of current zoning designations or to act as conservation or development overlay zones for land use planning (Brown, 2006, p. 103).

Although some work has been done to characterize the fuzzy nature of places Carver *et al.*, 2009; Gunderson & Watson, 2007; Lowery & Morse, 2012) few of these studies follow the example of Leung (1987) and defuzzify the boundaries between places to obtain an optimal boundary which is based on a collective opinion.

The combination of geolocated place attachment surfaces, the summation of multiple surfaces to create a consensus view, and the defuzzification of the summed surface to create a discrete boundary allows us to operationalize people's understandings of place. Boundaries created from public input can finally be overlaid with cadastral boundaries to identify those properties that might be purchased to bring artificial boundaries into better agreement with subjective boundaries produced by the PAS. This method can be used to improve parks, retail, business, historic and tourist districts.

6.2.3 Using the PAS for Planning

Since the beginning of this project, there have been a number of completed and scrubbed infrastructure projects in the park. The overall map of place attachment for the park helps to explain visually why some of these projects have been virtually unopposed, while others have led to strong public opposition, including civil disobedience.

Understanding the geography of place attachment gives us the ability to introduce richer, more relevant information at the beginning of the planning process. This reverses the traditional "plan and then get feedback" mechanism, instead encouraging the proactive, transparent, and participatory engagement that the public demands prior to the commencement of formal planning activities. Such a method of planning may be more difficult at the outset, but the result is a linear planning process with fewer potential issues at the end and a higher overall chance of success. This reduces expenses by encouraging changes at the beginning of the process, when few resources have been committed, and avoiding repeated rounds of public consultation about plans that been made without input by the public.

We will analyze the boundaries of the park and adjoining parcels critically, making use of a tool that helps planners to determine which areas of the park may be altered. It can help planners set up land swaps to improve the layout and design of the park. Our method provides a new tool that allows for the understanding of place attachment. This offers new ways of examining the importance of place, and new ways of managing important places. Place attachment has been made concrete, so that a solid understanding of place attachment can drive better-informed planning decisions.

6.2.4 Defining Subjective Boundaries

The subjective boundary of Colliery Dam Park might be defined in several ways; we will briefly mention the different methods considered prior to discussing the solution chosen. For the purposes of this analysis, we will assume that the subjective boundary of Colliery Dam Park was static during the period of data collection. We extracted three dimensions from the multidimensional data set collected: the Cartesian X, Y map coordinates, and the Z coordinates representing the place attachment of the surface. This was represented as a 2.5 m × 2.5 m (8.2 × 8.2 ft.) raster in the PAS.

One of the benefits of representing place attachment surfaces as rasters is that there are many different ways of analyzing them. The challenge is to find a procedure that is methodologically sound and produces a defensible result. Ideally, the subjective boundary of the park will be a single polygon with no islands (holes) in the middle of it. This ideal may not be achieved, but the simpler the results, the easier they are to use and to integrate into the planning process.

Hydrological tools have been employed in the past to find low points in an inverted surface. We can then "fill" the low areas to identify each peak in the surface. This approach works well on a smooth surface, but fails with the complicated surface shown in Figure 6.3 on page 140.

Running a smoothing algorithm on the summed place attachment surface, such as using the mean function with a large (e.g. 9 x 9 pixel) moving window might be one way to simplify the surface. However, doing this fundamentally changes the nature of the data.

An approach based on how biologists calculate wildlife home range using radio collar tracking data was considered. Hooge and Eichenlaub (2000) have developed a number of GIS-based tools to help identify an animal's "home range." When an animal has been radio collared, the collars return many points with the X and Y-coordinate and the time at which the data were collected. Unfortunately, this approach requires a probabilistic surface, not a fuzzy surface, which is an incorrect approach. Burrough explains the differences between fuzziness and probability:

> Fuzziness is not a probabilistic attribute, in which the degree of membership is linked to a given statistically defined probability function. Rather, it is an admission of the possibility that an individual is a member of a set, or that a given statement is true (Burrough, 1996, p. 18).

Others, such as Fisher (1996), Hill and Binford (2002) and Schneider (1996) caution against treating fuzzy surfaces as probability surfaces and vice-versa; for this reason, a statistical approach was not used in the analysis of surfaces. Although traditional, Boolean logic is a subset of fuzzy logic, and thus Boolean features can be represented using fuzzy surfaces in a GIS, probability surfaces are not a subset of fuzzy surfaces. Probability surfaces represent the probability of an event occurring at a particular location, but fuzzy surfaces represent the degree of membership present at a location. For example, with a probability surface, we might say that there is a 40% probability that a person will be found in Colliery Dam Park on a winter day. A fuzzy surface might indicate, based on all the study participants examined, that a particular location is 0.8 within Colliery Dam Park, 1.0 within the neighborhood of Harewood, and 0.4 within the University District.

The fundamental issue that must be addressed in this chapter is how to represent a complicated multidimensional shape as an understandable two-dimensional polygon or set of polygons that best represents the boundaries of a place. Boundaries can be judged on the criteria of shape, compatibility with existing lots, and acceptability of the solution by planners and the public, or else the results will simply be rejected.

Massey states, "If it is now recognized that people have multiple identities then the same point can be made in relation to places. Moreover, such multiple identities can either be a source of richness or a source of conflict, or both" (Massey, 1997, p. 321). Making sense of these differing viewpoints is a challenge, but if a participant's perception of a place can be represented concretely on a map, as opposed to a nebulous and shifting verbal description, it is much easier and faster for planners to examine the role and importance of place and engage participants in consensus building. Having concrete visual representations makes it possible for each participant to state (and potentially convince others of) their point of view. These allow differences between perceptions to be articulated, accepted or respectfully disagreed with. Such clarity can reduce or dissipate the fog surrounding public meetings quickly, allowing participants to get beyond posturing to discuss specific points of difference.

Using subjective boundaries derived from participant input can help us create plans that are less controversial, less expensive and which represent the needs of local residents better. The method we describe provides some useful alternatives for park expansion, which may be worth considering. The method is strictly defined and repeatable; using a computer program to identify areas of interest ensures that the same results will be produced for the planner's consideration when the same inputs are provided.

6.3 Creating Candidate Survey Boundaries

The software module described in this chapter has two main functions: the creation of candidate survey boundaries, and the evaluation of those boundaries. Functionally, finding the best boundaries involves an optimization procedure that selects the best of a large number of options using an algorithm. Before the candidate survey boundaries can be examined, however, they need to be created from the summed place attachment surface derived from the participant responses stored in the PAS.

6.3.1 Criteria for Suitable Boundary

Being able to create a crisp, closed (artificial) boundary from a summed place attachment surface provides a bridge between subjective and artificial boundaries, allowing planners to be more sensitive to the needs of local residents when parcels need to be assembled or subdivided.

Because the three-dimensional surface is complex, many irregularly shaped polygons containing holes can be created. This leads to complicated discrete boundaries that are undesirable; we would like to choose the best from the many options available. The objectives are to define artificial boundaries that are relatively simple in shape, can be operationalized, and which are acceptable to planners and study participants.

Ideally, the resulting artificial boundaries should have the following characteristics:

1. the areas formed should not be overly complex. We want a small number of uncomplicated polygons that do not contain too many holes;
2. the boundaries should be similar in shape to existing lots, can be created from assemblages of parcels, or can be easily subdivided from larger plots of land; and
3. the areas should "make sense" for planners and should be recognizable to members of the public as places that they described.

We evaluated multiple discrete boundaries using a suitability function that emphasizes the simplicity and significance of the output regions. To prepare the data for evaluation by the suitability function, the summed place attachment surface is ***sliced*** into a number of ***α-cuts*** of equal vertical range (Klir & Yuan, 1995; Leung, 1987) using the ArcGIS **Slice** command (ESRI, 2017f). The value of α ranges from $1/n$ to n/n, where the value of n, the number of slices to be made, is defined in advance. Beginning at $\alpha = 1$, we concatenate all slices greater than or equal to α together to create what is known as an α-cut. As the value of α increases, only equal or higher values are included in the ***concatenation***. With each successive concatenation, a more restricted area is defined with one more slice lopped off the bottom.

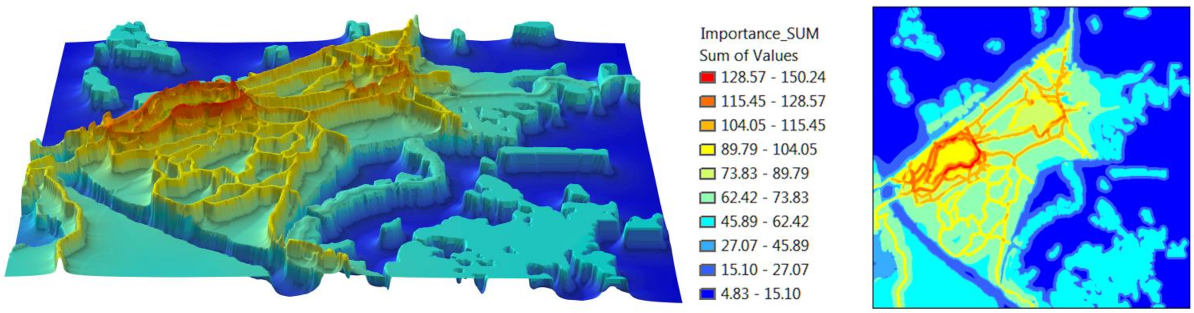
For each α-cut, the resulting discrete boundary is analyzed by a suitability function that evaluates the shape of the boundary based on the criteria mentioned above. The higher the value of the suitability function, the more the result "makes sense," and the more likely it is to be compatible with existing parcels and land uses. The simpler the polygons resulting from the α-cut, the fewer legal land parcels they are likely to intersect. When we have multiple long, thin areas, many property parcels may be intersected, requiring the involvement of many stakeholders and potentially, a long process for the acquisition of property rights. On the other hand, a small number of compact polygons tend to intersect fewer parcels, significantly reducing the number of stakeholders and negotiations required. The fewer individuals involved, the greater the likelihood that a project will proceed past the negotiation stage to implementation.

Whether or not the results are acceptable to planners and members of the public is more difficult to assess, and is left to the expert opinion of planners and local residents. To isolate the best candidates, we create a shortlist of the most promising groups of polygons so that the work of the planner or citizen is spent productively.

6.3.2 Graphical Overview of Process

Figure 6.4 shows a simplified example of the data processing using only 10 α-cuts. This example creates slices that are too "thick" to provide meaningful answers, but illustrates the general process of creating and evaluating discrete boundaries.

In Figure 6.4, subgroups of slices are evaluated, and the results are shown in the database table in Figure 6.4c. In our example, we use n = 10 slices. Concatenation_1_10 contains all slices [1, n]; Concatenation_2_10 has one less slice on the bottom [2, n], and we continue up to Concatenation_10_10 [n, n]. Each concatenation creates areas of contiguous pixels, separated by unoccupied space. These are referred to by ESRI as "region groups." For each concatenation, the number of areas is calculated using the ArcGIS **Region Group** command



a.　b.

Concatenation	NumRegionGroups	AdjustedInverseGroups	PeakHeight	PeakSignficance	Suitability	Rank
Concatenation_1_10	1	0.50	0.00	0.36	0.18	6
Concatenation_2_10	11	0.60	0.05	0.43	0.26	5
Concatenation_3_10	14	0.65	0.09	0.48	0.31	3
Concatenation_4_10	19	0.61	-0.26	0.00	0.00	9
Concatenation_5_10	9	0.83	0.10	0.49	0.41	2
Concatenation_6_10	3	0.95	0.47	1.00	0.95	1
Concatenation_7_10	19	0.61	-0.23	0.03	0.02	8
Concatenation_8_10	25	0.50	-0.15	0.15	0.07	7
Concatenation_9_10	19	0.54	0.09	0.48	0.26	4
Concatenation_10_10	11	0.50	0.00	0.36	0.18	6

c.

d.　e.　f.

Figure 6.4. How α-cuts can be used to extract an artificial boundary from a summed surface, using only 10 slices. a) the initial summed surface; b) a planimetric view of the surface divided into 10 slices; c) the table of results used to compute the overall *Suitability* and *Rank*, with Concatenation_5_10 selected; d) The slices that remain in Concatenation_5_10 after slices 1-4 have been removed; e) the 9 region groups in Concatenation 5_10 (shaded), and the physical barriers that are used to separate them (red lines); f) the final smoothed artificial boundary once the extraneous polygons and holes have been removed.

(ESRI, 2017g) and is stored in the *NumRegionGroups* column in the database table shown in Figure 6.4c.

Once a ranked result has been identified for further examination, we want to concatenate all slices greater or equal to α (Figure 6.4d) to create an α-cut. The α-cut for α = 5 is shown in Figure 6.4e. Although this is ranked second, it was chosen because we want areas from the lower range of α values, which represent larger areas. Artificial boundaries such as fences or busy roads that may prevent travel are shown in red on top of the gray polygons. These barriers are used to split up polygons, except where they permit travel beneath overpasses and across sidewalks. In Figure 6.4f, the resulting concatenation is converted to vector (polygon) format and cartographic enhancement is applied to improve the appearance of the result for public presentation.

6.3.3 Detailed Process

This section goes into the details, formulae, and algorithms employed to perform the processing described in Figure 6.4.

In Figure 6.4a, the summed place attachment surface presents a "democratic view" of the place attachment of the study area, based on the input of all study participants. To do this, we calculated an algebraic sum of all the place attachment surfaces (Equation 6.1).

$$s_x = \sum_{i=1}^{n} s_i \qquad \textbf{Equation 6.1}$$

Where:

s_x is the summed place attachment surface;
n is an arbitrary number of slices chosen in advance; and
s_i are the place attachment surfaces produced by the study participants.

Our objective is to extract a two-dimensional shape from the summed surface, a complex three-dimensional object. In Figure 6.4b, the summed place attachment surface has been sliced into 10 discrete slices of equal depth (n = 10). The lowest value in each slice represents one of the 10 α-values that have been selected for this analysis.

To create a single, discrete linear boundary around the summed surface, we use an α-cut (Klir & Yuan, 1995; Leung, 1987) to defuzzify the summed surface. The α-cut returns all Z-values greater than or equal to α. The resulting three-dimensional raster surface is flattened and vectorized to create one or more polygons that can be easily mapped for planning activities.

How can the value of α be best determined? Leung leaves the definition of α open: "The physical implication of restricting the boundary to a precise value is that we are certain in deciding how much of an individual characteristic a spatial unit must possess to belong to the designated region" (Leung, 1987, p. 128). However, since we cannot determine α in advance, given the complexity of place dynamics, this becomes an optimization problem; we must consider multiple options and choose the best. Because the number of possible α values is unlimited, we select a finite number of values. We tested from 10 to 2500 α-cuts, and found that increasing the number of α-cuts produces additional detail, but does not create unexpectedly high or low *Suitability* values.

Because of the complexity of the three-dimensional shape from which each polygon is created, multiple polygons may be produced if the α-cut intersects several "hills" in the surface. Most α values result in boundaries that are nonsensical, but a small proportion of them will produce boundaries that make sense, providing new perspectives that a planner might not have considered.

In Figure 6.4c, a database table is populated and then employed to facilitate the calculations required to process and rank the candidate boundaries. The following columns are listed in the table in Figure 6.4c:

- ***Concatenation***: The name of the slices that have been concatenated, for example Concatenation_6_10 contains slices 6-10, and would represent the top half of all Z values.
- ***NumRegionGroups***: The number of distinct areas that are produced for each concatenation.

- ***AdjustedInverseGroups***: The adjusted inverse of *NumRegionGroups,* which corrects for an issue with spatial autocorrelation.
- ***PeakHeight***: The height of the smoothed peak relative to its neighbors. If one or both neighbors have higher values, the *PeakHeight* value may be negative.
- ***PeakSignificance***: The *PeakHeight* values, scaled to a range of [0,1].
- ***Suitability***: The combined suitability, based on *PeakSignificance* and *AdjustedInverseGroups.*
- ***Rank***: A ranking of *Suitability,* from highest to lowest.

The first step in evaluating this shape is to determine how many contiguous areas were created by the α-cut. We use the **Region Group** (ESRI, 2017g) command to count the number of contiguous areas in each concatenation, and these values are used to populate the *NumRegionGroups* column.

The *AdjustedInverseGroups* column incorporates the importance of having as few regions as possible. However, when we are dealing with the first and last few concatenations, the number of regions is strongly affected by spatial autocorrelation. Spatial autocorrelation is the tendency for nearby objects to have similar values, whereas distant objects tend to have dissimilar ones. The problem stems -- not from the absolute number of polygons produced -- but from the number of polygons produced relative to the number that *could be* produced at a particular α value. At low and high α values, the spatial autocorrelation between polygons and non-polygons tends to be positive. The study area is either predominantly covered by a polygon, or it is predominantly empty space. Since nearly each pixel has the same value as its neighbor, this leads to positive spatial autocorrelation values. At moderate α values, there are more likely to be patches of polygons and non-polygons interspersed (i.e. the spatial autocorrelation is likely to be closer to zero or even negative). Thus, at low and high α values, having a small number of polygons is likely; with moderate α values, having a small number of polygons is quite unusual. In practical terms, for the first and last of the concatenations in Figure 6.4c, all the pixels tend to have the same values, i.e. 1 (belonging) for Concatenation_1_10, and 0 (not belonging) for Concatenation_10_10. *AdjustedInverseGroups* removes the effect of the spatial autocorrelation, so that concatenations with few region groups are highlighted only where they are unlikely to be the product of spatial autocorrelation.

To calculate *AdjustedInverseGroups,* we begin by inverting and normalizing the number of region groups. The initial calculation (Equation 6.2) rates α-cuts having few regions highly and those having many regions poorly.

$$n = \begin{cases} \frac{\mathrm{Max}(r) - r}{\mathrm{Max}(r) - 1} & if\ Max(r) > 1 \\ 1 & if\ Max(r) = 1 \end{cases}$$ **Equation 6.2**

Where:
n is the normalization of the inverse of *NumRegionGroups*; and
r is *NumRegionGroups.*

To compensate for spatial autocorrelation, we introduce a correction factor. This takes the form of a modified sine wave function, which is used to adjust *n*, the normalization of the inverse of *NumRegionGroups* downward at low and high α levels (Equation 6.3).

$$c = sin\left(\frac{(\propto\ -1)}{s-1}\pi\right)$$ **Equation 6.3**

Where:

c is the autocorrelation correction factor for the normalization of the inverse of *NumRegionGroups*;

α is the threshold value representing the minimum Z value in the summed surface; and

s is the total number of slices used.

Equation 6.3 scales [0,n] to [0,π], and then generates a sine value of 0 at each end and 1 in the middle. The sine wave function is scaled to give it a range of [0.5, 1.0].

The autocorrelation correction factor (c) is then multiplied by n, the normalization of the inverse of *NumRegionGroups* (Equation 6.2) to obtain *AdjustedInverseGroups* (Figure 6.5).

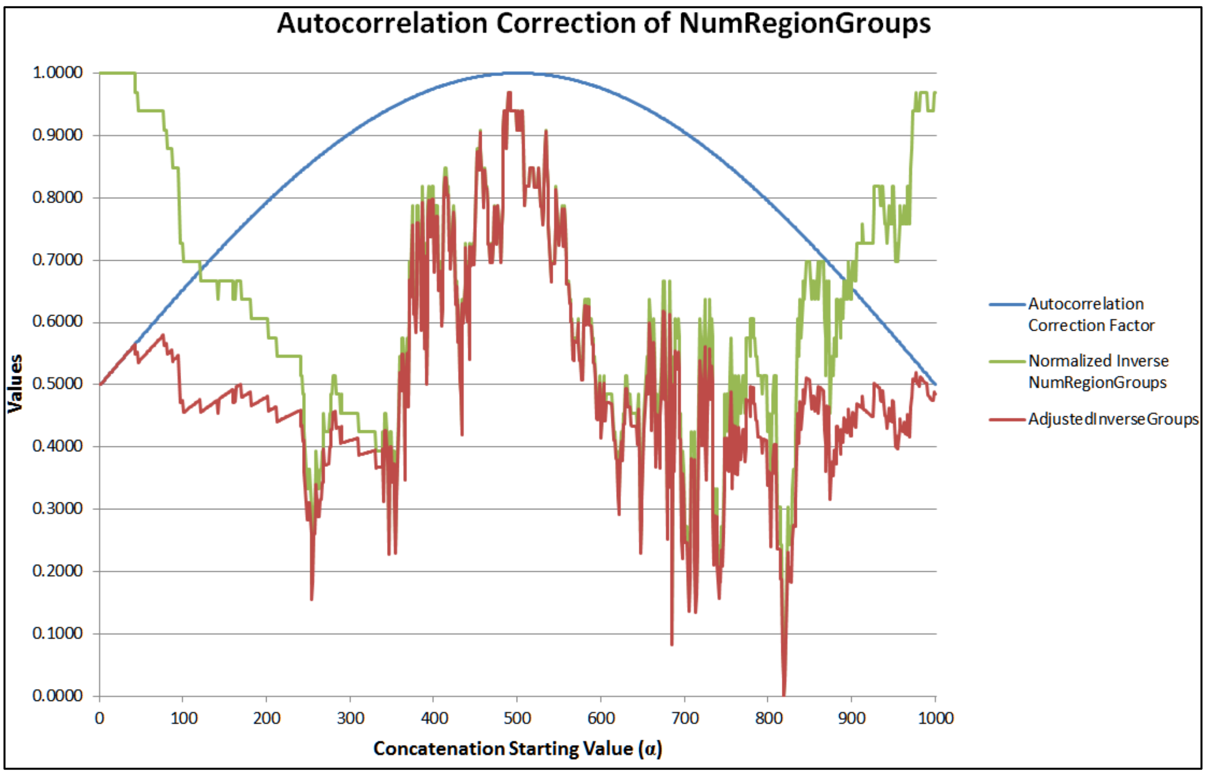


Figure 6.5. Correction of the normalized inverse *NumRegionGroups* using an autocorrelation correction function to generate *AdjustedInverseGroups* for 1000 slices.

The peaks shown in *AdjustedInverseGroups* in Figure 6.5 represent α-cuts whose boundaries are relatively uncomplicated when compared with their neighbors. Unfortunately, the graph of *AdjustedInverseGroups* is "noisy" and it is difficult to choose important peaks from the many possibilities presented. To resolve this issue, we examined the height of the peaks relative to their neighbors several α values above and below their position. This helps to highlight whether a peak is locally significant.

The degree of filtering of peaks should be proportional to the total number of slices being analyzed. If there are many slices, we want a stronger filter than if there are only a few slices. The objective is to avoid overwhelming the planner with dozens of options when many slices are created.

The position of the comparison values used for calculating the prominence of the central peak is defined by using an odd-numbered window. The window size is calculated based on the number of slices that are created for the analysis. The formula used is:

$$s = round(log_{10}(n) * w)) \qquad \textbf{Equation 6.4}$$

Where:

s is the window size, in slices;

n is the number of slices used in the analysis; and

w is a parameter for adjusting the width of the window. Currently this parameter is set to 3.

Except where options are constrained near the first and last slices, values are chosen from the lower and the upper ends of the window. The resulting calculation shows the sum of the run-up from each end of the window to the peak being examined, to determine *PeakHeight*, as follows:

$$p = \begin{cases} (i_\propto - i_1) + \left(i_\propto - i_{\propto + \left(\frac{s}{2} - 0.5\right)}\right) & when \ \propto - \left(\frac{s}{2} - 0.5\right) \leq 0 \\ \left(i_\propto - i_{\propto - \left(\frac{s}{2} - 0.5\right)}\right) + (i_\propto - i_n) & when \ \propto + \left(\frac{s}{2} - 0.5\right) > n \\ \left(i_\propto - i_{\propto - \left(\frac{s}{2} - 0.5\right)}\right) + \left(i_\propto - i_{\propto + \left(\frac{s}{2} - 0.5\right)}\right) & otherwise \end{cases}$$ **Equation 6.5**

Where:

p is the *PeakHeight*;

i_α is the *AdjustedInverseGroups* value at the current position;

s is the window size, in slices; and

n is the number of slices used in the analysis.

Note that in many circumstances, *PeakHeight* may be negative; in other words, the *AdjustedInverseGroups* value is less than its neighbors on the graph. Figure 6.6 shows how the calculation in Equation 6.5 acts as a filter to emphasize local prominent peaks and de-emphasize lesser peaks. Once the filter has been applied, the *PeakHeight* is then normalized to a range of [0,1].

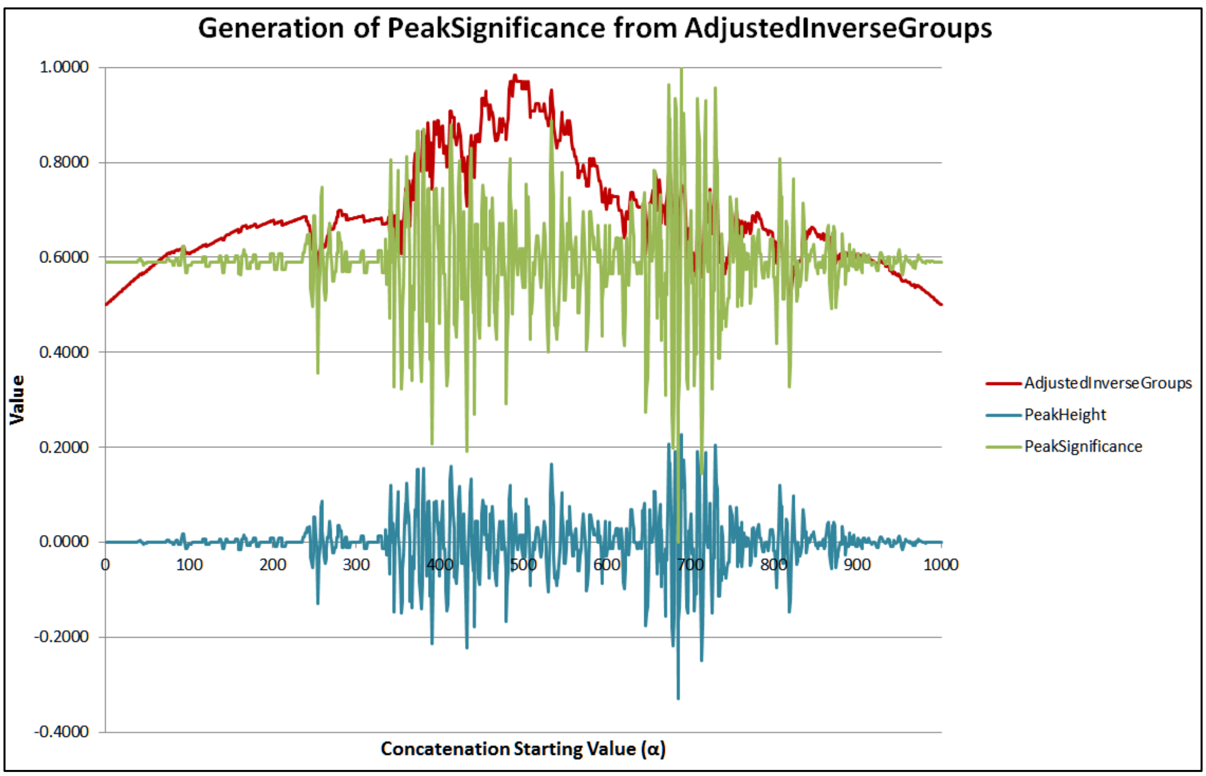


Figure 6.6. Peak Significance is generated by calculating the *PeakHeight* on *AdjustedInverseGroups* using a moving window, and then by normalizing it to a range of [0,1].

The final graph from which we determine a shortlist of α values is the combination of two factors. First, we have *AdjustedInverseGroups*, the inverted and adjusted number of areas for each α-cut, which indicates the overall importance of areas, once we have adjusted for the autocorrelation problem. The fewer region groups (polygons) that we have, the more useful a potential solution is to the planner. Second, we have the *PeakSignificance* value, which emphasizes locally important peaks in the graph, and suppresses nearby but lesser peaks based on a filter function. Multiplying the two factors together gives us the *Suitability* value shown in Figure 6.7, from which peaks are extracted and ranked to produce candidate boundaries for further examination by the planner.

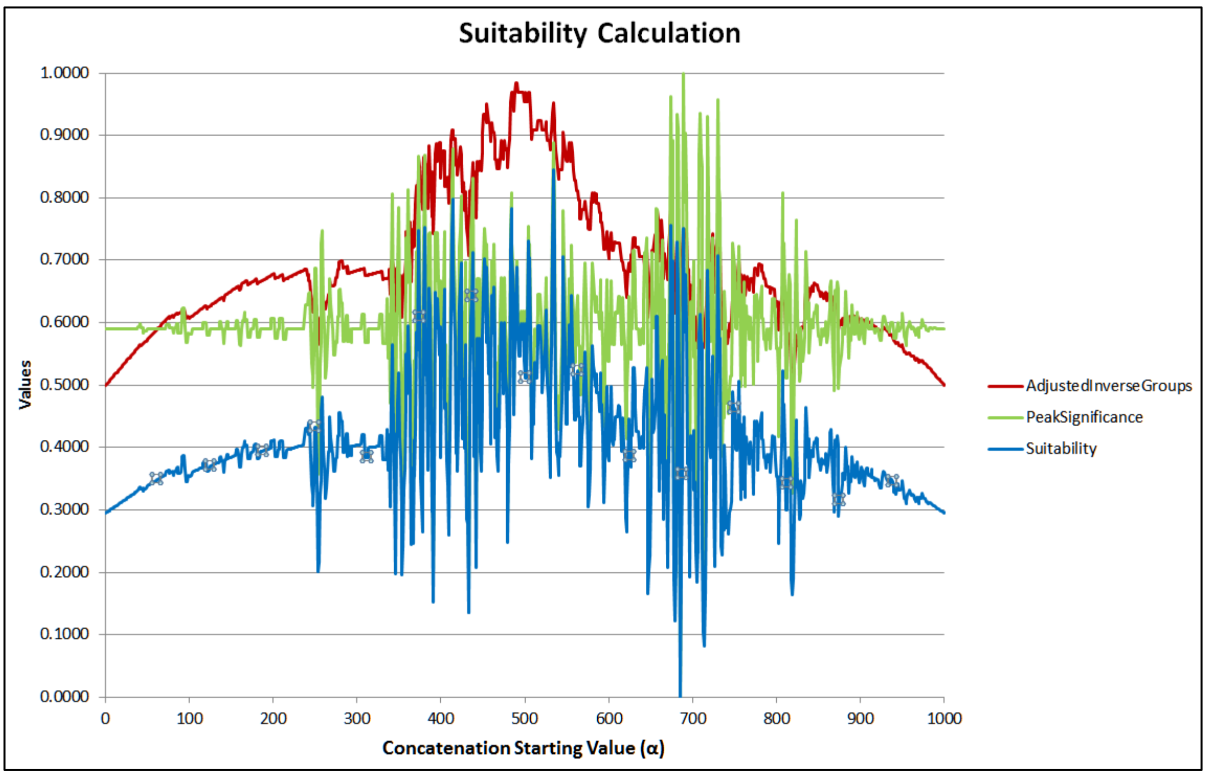


Figure 6.7. The *Suitability* value is derived by multiplying *AdjustedInverseGroups* by Peak Significance.

The *Suitability* values are then sorted and ranked, with matching *Suitability* values being given an equal ranking. The *Rank* values are then divided into "core" and "periphery" areas. To do this, the positions of the highest and second-highest *Suitability* peaks on the graph are determined, and the value mid-way between these is defined as the dividing line between core and periphery (Figure 6.8). Although it seems logical to separate the core from the periphery at the median α value, there is significant variability in the positioning of the peaks, such that there may be a cluster of prominent peaks above the median, and nothing below, or vice-versa. The solution is to pick the two highest peaks on the graph, assign the one with the highest value to the core and the one with the lowest value to the periphery and then divide the remainder of the peaks between them when ranking. The most prominent peaks are examined in descending rank order, and are assigned to the core or periphery based on their position relative to the dividing line.[5]

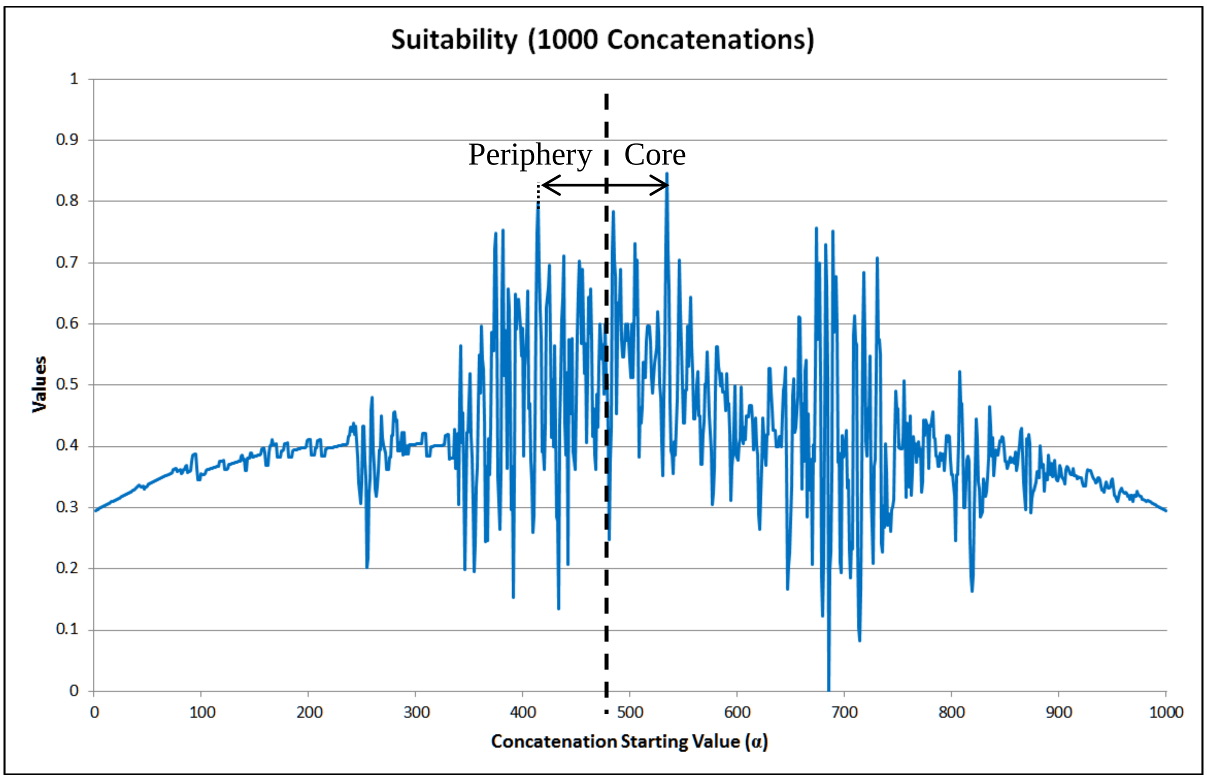


Figure 6.8. Graph of *Suitability* values for 1000 concatenations, showing the dividing line between core and periphery located at α = 474, midway between the two highest peaks at α = 414 and α = 534.

[5] This is the reason why, in Figure 6.4c, the second highest Suitability value has been highlighted. The divide between core and periphery occurs between rank 1 and rank 2, which would have a *Suitability* midway between 0.95 and 0.41, or at 0.68. Because the *Suitability* of rank 1 is higher than the *Suitability* of rank 2, rank 1 is considered the highest value for the core and rank 2 is considered the highest value for the periphery.

Based on the rankings of the *Suitability* values, the planner is free to examine as many candidate areas as he or she sees fit. In Figure 6.4d, we are presented with all of the slices that are equal to or above the highlighted Concatenation_5_10. To regenerate a candidate area, we concatenate all of the slices greater or equal to α (Equation 6.6).

$$M = \begin{cases} 1, \text{if } \sum Z_k \geq \alpha \\ 0, \text{otherwise} \end{cases}$$

Equation 6.6

Where:
M is the membership in the α-cut;
Z_k is the raster representing fuzzy region k; and
α is the starting value of a particular concatenation.

We then process the boundaries of the concatenated area in Figure 6.4e. To remove the lines representing barriers from the membership raster, the barrier lines are first converted to a raster using the **Polyline to Raster** command (ESRI, 2017h). The **Reclassify** command (ESRI, 2017i) is next used to convert the pixels representing the barrier to NoData, with all other pixels in the study area being given the value of 1, to create a mask raster. Finally, the values of the membership raster are extracted based on the mask raster using the **Extract by Mask** command (ESRI, 2017j), so that the areas along the barriers are given a value of NoData, whereas all other values within the membership raster retain their value of 1.

The resulting raster has the original region groups divided by the barriers that happen to pass through them. These regions are subsequently converted to vector data using the raster to polygon command, so that they can be processed by the vector cartographic generalization tools.

Once we have a polygon representation of the concatenation, the **Aggregate Polygons** command (ESRI, 2017k) is run twice to clean up the results. A number of parameters have been set to adjust the appearance of the output. On the first pass, the **Aggregate Polygons** command is used only to remove inconsequential polygons from the results. Polygons must be larger than 4% of the area of the largest polygon in the data set or they will be deleted. On the second pass of **Aggregate Polygons**, it is used to fill in holes and merge any remaining polygons together. No islands (holes) smaller than 0.79 ha (1.95 ac.) (equivalent to a circle with a radius of 50 m or 164 ft.) are allowed in the output, and any polygons lying within 5 m (16 ft.) of each other will be merged together.

Note that in some cases, nearby polygons larger than 4% of the area of the largest polygon, but which are separated by less than 5 m (16 ft.) will be reconnected, even though they were separated previously by the barriers.

Different types of barriers present differing degrees of permeability; a freeway is more difficult to cross than a one-lane road, and a barbed-wire fence is even more difficult to cross than a freeway. Larger polygons having a higher human or animal population[6] will exert a greater number of challenges to a barrier, with a potentially higher number of crossings as a result. For example, black-tailed deer (*Odocoileus hemionus*), have been observed crossing boundaries, where they use holes in a chain link fence to allow for travel across Nanaimo Lakes Road between Colliery Dam Park and a forested section of the Nanaimo Military Camp.

[6]Larger polygons may also support greater biodiversity, yielding species of different sizes and capabilities that are able to cross barriers designed for humans.

Figure 6.4f shows the results once the polygons have been cleaned up. The **Smooth Polygon** command (ESRI, 2017l) has been used to apply a PAEK (Polynomial Approximation with Exponential Kernel) algorithm with a 50 m (164 ft.) filter size to make the output less angular, both improving the appearance of the output, and reducing the likelihood that the result will be interpreted as being spuriously accurate.

6.3.4 Regeneration of Boundaries

As mentioned previously, we created between 10 and 2500 slices. We found that there was a balance between the amount of detail provided and the processing requirements, and more than roughly 1000 slices resulted in diminishing returns. Further increases in the number of slices led to many adjacent slices that were nearly identical, providing the planner with no additional options to explore, despite the additional data processing requirements. For 1000 slices, the report produced by the PAS is shown below, in Table 6.3.

6.3.5 Shortlist of Candidate α Values

The number of candidate α values displayed in the report is controlled by an equation that incorporates the number of slices (Equation 6.7). The higher the number of slices, the greater the probability that two peaks will be reported from sequential α values. In such a case, it makes sense to ignore one of the neighboring α values. This, of course, reduces the number of meaningful scenarios that are available for the planner's consideration. For this reason, we increase the number of α values reported as the number of peaks increases, to ensure that there are an adequate number of areas of interest presented for consideration.

$$r = round(log_{10}(n) * m) - a$$ **Equation 6.7**

Where:

r is the number of core and periphery results;
n is the number of slices used in the analysis;
m is a parameter for adjusting the number of results shown. Currently this parameter is set to 3; and
a is a parameter to reduce the number of results produced when *n* is small. Currently, this is set to 2.

Based on Equation 6.7, the top *r* peaks are shown for core and periphery (Table 6.3).

```
Top 7 Results for Core and Periphery
Peak 1 (Core): Position 534
Peak 3 (Core): Position 484
Peak 4 (Core): Position 674
Peak 6 (Core): Position 689
Peak 9 (Core): Position 533
Peak 10 (Core): Position 504
Peak 11 (Core): Position 682
Peak 2 (Periphery): Position 414
Peak 5 (Periphery): Position 381
Peak 7 (Periphery): Position 413
Peak 8 (Periphery): Position 374
Peak 12 (Periphery): Position 373
Peak 15 (Periphery): Position 438
Peak 20 (Periphery): Position 452
Run Complete.
```

Table 6.3. Shortlisted positions for best core and peripheral areas.

Peaks with high α values represent very small areas on the ground. Conversely, lesser peaks that occur at lower α values occupy a larger zone and represent a more substantial and useable park area. For this reason, we divide the peaks into smaller areas that represent the "core" of the park, and larger regions that represent the "periphery." For generating an outline of the park, we are interested in the periphery, those places that are broadly occupied by park users. Once the planner has made a final decision on which α-cut will be examined in detail, the starting concatenation value can be entered into the PAS to regenerate the areas on the map.

6.3.6 Role of the Planner in Interpreting Results

Having a familiarity with the area in question is important to ensure that the artificial boundaries make sense in geographic terms. Are too many or too few locations identified? Does the artificial boundary that corresponds with a highly ranked α-cut reflect the general understanding of the area? If not, a nearby slightly less well-ranked candidate may be the better choice. While the ranking procedure can help to shortlist a small number of options, the planner, with his or her understanding of broad issues and ability to visualize results, remains critical in the process.

6.4 Operationalizing the Selected Subjective Boundaries

An examination of the report for the best peripheral areas led us to choose Concatenation_414_1000, Concatenation_381_1000 and Concatenation_438_1000 for further examination (Table 6.4). Some of the other good candidates (α = 413, 374, and 373) were skipped because they were similar to those that had already been chosen.

Concatenation	Significance	Total Area (ha)
Concatenation_414_1000	0.80	45.84
Concatenation_381_1000	0.75	56.29
Concatenation_438_1000	0.71	40.23

Table 6.4. Parameters for concatenations defined by selected artificial boundaries.

Each artificial boundary candidate displays important qualitative differences from the others. Concatenation_414_1000 (Figure 6.9) includes the Nanaimo Parkway Trail and portions of 801 and 1150 Nanaimo Lakes Road which lie across the Nanaimo Parkway from the main body of the park. Some of the lesser used parts of the existing park, such as the portion of Chase River below the lower dam (739 Howard Avenue) and a swampy area along Harewood Mines Road are missing, as are some places along the Nanaimo Parkway.

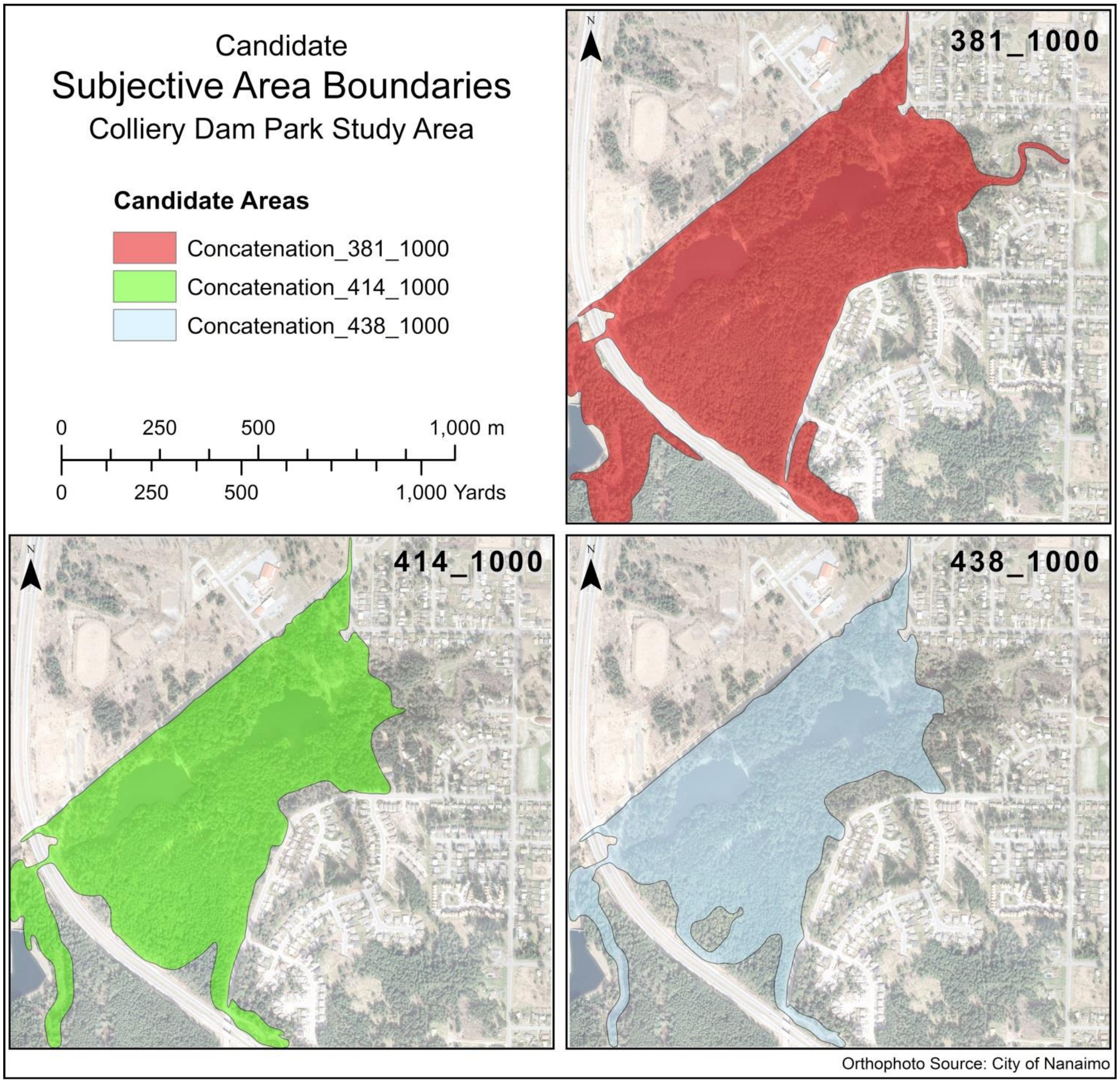


Figure 6.9. Candidate artificial boundaries within the study area. Concatenation_381_1000 includes large portions of 801 and 1150 Nanaimo Lakes Road within the study area, plus a portion of Janes Park and an area along the Parkway Trail.Concatenation_414_1000 removes undeveloped pieces of forest, restricting part of the selected area to a buffer around existing trails, and Concatenation_438_1000 removes the infrequently accessed forest within 1150 Nanaimo Lakes Road at the southern border of the map.

Concatenation_381_1000 includes some of these missing areas, expands the area along the Nanaimo Parkway Trail south of the park and includes a portion of Janes Park (the small park running along Harewood Creek to the south of Colliery Dam Park), as well as expanding the area across the Nanaimo Parkway from the main body of the park. Concatenation_438_1000 has a smaller area than Concatenation_414_1000, and includes less of the park area, a narrower area on the other side of the Nanaimo Parkway from the main park body, and a large void near Nanaimo Parkway, which is surrounded by the park's trail system.In these three variations, we can see some options for expanding Colliery Dam Park that might not have been considered without the suggestions provided by this analysis. Concatenation_381_1000 presents the possibility of having the lot at 1150 Nanaimo Lakes Road subdivided to allocate areas of low place attachment for residential development, while retaining areas of higher place attachment for parkland. This would have to be considered carefully, however, because the Trans-Canada Trail runs just to the south of the map and would be affected. Given that this slice extends along the Nanaimo Parkway on both sides, it presents the possibility of connecting the two halves of the expanded park with an overhead walkway or a land bridge. This would augment the existing tunnel/walkway that currently runs beneath the Nanaimo Parkway along the Chase River.

Once the alternatives have been considered and a final boundary has been decided upon by the planner, it can be used with other planning methods and tools. Using the final artificial boundary with GIS to identify parcels makes the subjective boundary useable in the planning world.

The three concatenations chosen for closer examination were overlaid with the parcels inside the study area using the **Union** command (ESRI, 2017s). All three results include the majority of Colliery Dam Park; portions of some of the other lots have also been proposed as park additions. A summary of the percentage of the existing and proposed Colliery Dam Park parcels affected by each concatenation is presented in Table 6.5.

Concatenation	Percentage of Colliery Dam Park Parcels			Percentage of Proposed Expansion Parcels		
	635 Wakesiah Ave.	645 Wakesiah Ave.	739 Howard Ave.	801 Nanaimo Lakes Rd.	1150 Nanaimo Lakes Rd.	1151 Nanaimo Lakes Rd.
Concatenation_381_1000	98.38	96.83	49.01	33.70	26.74	0.00
Concatenation_414_1000	98.17	88.11	0.00	29.96	21.85	0.00
Concatenation_438_1000	95.97	82.38	0.00	24.65	18.06	0.00

Table 6.5. Percentage of the six lots affected by the three proposed artificial boundaries. Percentages calculated do not include the portions of the lots that lie outside the study area.

If we look beyond the lots that are already being considered for expansion, some other options become available.

We can overlap the area(s) identified by our concatenation with parcels in the area. Where there is a significant amount of overlap between the concatenation and parcels, we can select the parcels for further consideration. Such parcels might be identified for immediate acquisition, long-term acquisition when it comes onto the real estate market or through expropriation if its immediate acquisition is critical. To identify such lots, we have set a conservative value of 50% overlap to identify those parcels that should be included (Figure 6.10). Based on this criterion, there is only one small private lot that overlaps Concatenation_381_1000, which merits further consideration (see arrow). This lot is one that the city may be interested in purchasing, particularly if parking needs to be expanded, since it is adjacent to the lower parking lot.

The results shown in Figure 6.10 have been sent to Kirsty MacDonald, Parks and Open Space Planner, City of Nanaimo, but no response has been received. Part of the reason for this may be that the procedure is experimental, and not all of the parcels being discussed are

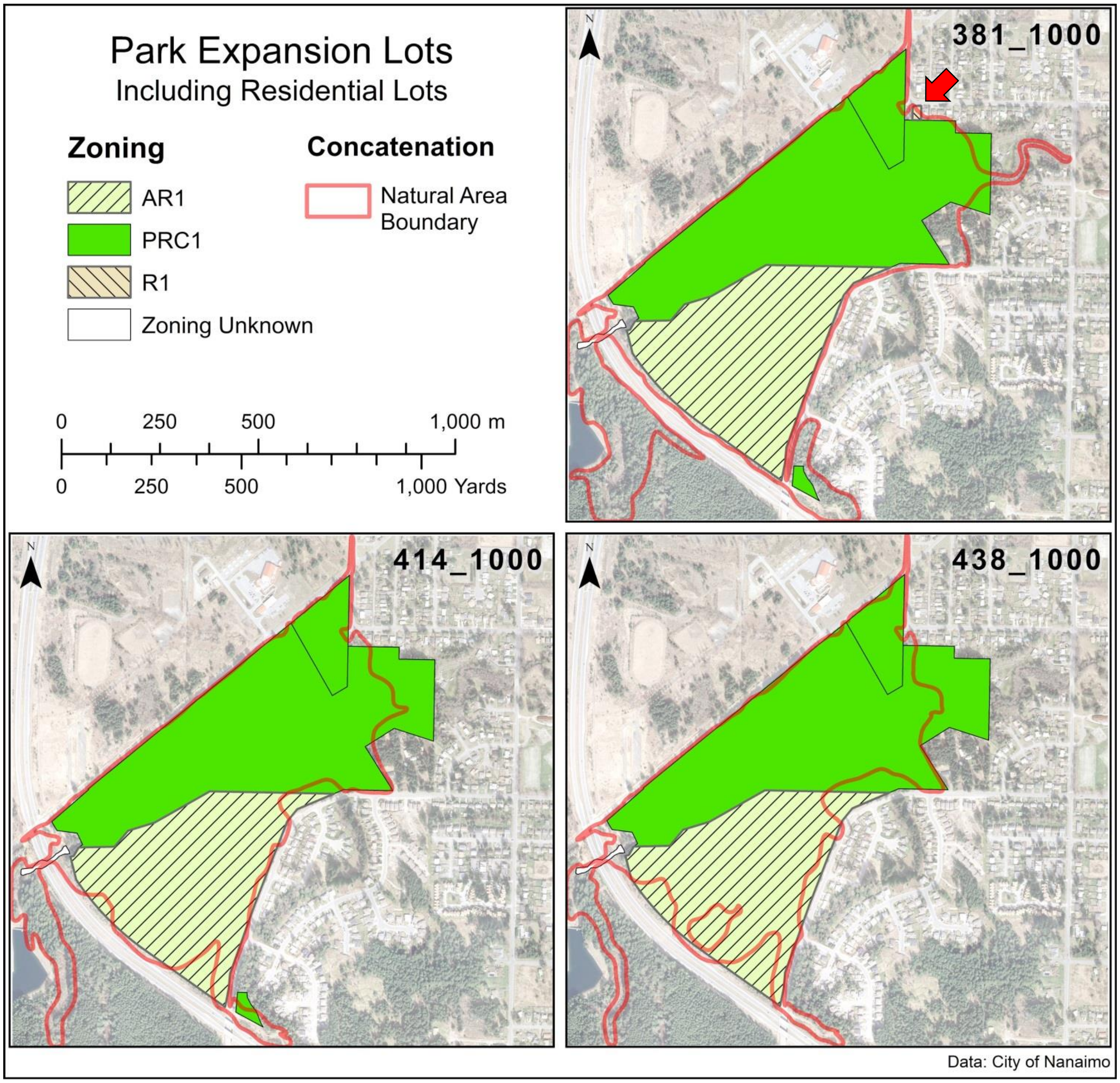


Figure 6.10. Approximation of Concatenation_381_1000, Concatenation_414_1000 and Concatenation_438_1000 based on lots located in the study area. The meanings of the zoning codes are shown in Figure 6.1.

fully contained within the study area (the study area was defined and data had been collected before I had become aware of the proposal to expand the park. To redo the analysis using a shortened timeframe with an expanded study area boundary is feasible, but does not appear to be a priority for the city at present.

The purchase of private lots for inclusion in public spaces can be contentious, for many of the reasons outlined in the previous chapters. One possible solution to this issue can be found in the development of the Gulf Islands National Park Reserve in Southwest British Columbia, which the Canadian Federal Government created in 2003 (Parks Canada, 2015a). Because the park reserve was created over a century after the area had been settled, the Federal Government offered life tenancy agreements to some property owners, such that they can continue to use and enjoy their properties, even though the properties have been purchased by the Federal Government for park use (Parks Canada, 2015b). For individual landowners, it ensures that the value of their estate is preserved; they get to know that the property will remain relatively unchanged, and have the satisfaction of knowing that park users will have the satisfaction of enjoying their property long into the future. For the Federal Government, the slow process of acquiring lands for the park will continue over decades, and eventually a new National Park will be formed. For today's public, the National Park Reserves offer many of the services of full National Parks (e.g. water, toilets, campsites, management), but the fragmented nature of the land holdings means that a reduced level of service is found at some locations (Parks Canada, 2015c).

6.5 Advantages of Using the PAS for Planning

There are three reasons why planners may find that the options presented by the PAS are helpful. First, being able to view three-dimensional representations of each participant's place attachment surface can help planners to understand the nature of the area being considered from the perspective of different individuals. Summing the surfaces to generate artificial boundaries gives us a way to see beyond cadastral boundaries, quickly assess "the will of the people" and work in a way that is more sensitive to the needs of local residents. Proposed changes can be evaluated to determine which are least and most likely to be accepted.

Second, being able to examine a range of options provides additional flexibility for the planner. Options that might not otherwise have been considered can be examined in public meetings to broaden the discussion about what is possible.

Third, the method described makes the planner's job easier towards the end of the process, since the initial plans were created using public input on place, and would already have been vetted by the public to some degree. Although there will be extra effort required before planning formally commences, administering a questionnaire and processing the data are fairly well-constrained activities that can be completed within a few weeks, particularly if they become standard procedures. Furthermore, there is no need for the survey to involve planners directly; planning technicians who have been carefully trained in survey and concatenation selection methods can complete the job with limited oversight by the planner. This assumes that well-defined rules can be set up to ensure consistent results. Getting closer to an optimal design prior to public consultation saves costs by avoiding unnecessary rounds of reanalysis and replanning. It also reduces the likelihood of activism, civil disobedience or lawsuits by disaffected members of the public; such actions are highly unpredictable and may delay a project by years, or derail it altogether.

Now that the programming of the PAS is complete, a team of full-time data collectors could survey several hundred people and enter the data into the system in about a week. Once the data are in the system, a planner or skilled operator could use the program to calculate the subjective and artificial boundaries of the study area with a few hours of operator time, and about a week of computer processing time, given the current program and computer capabilities. The amount of processing time will decrease as the program is made more efficient and computer speeds increase.

The methods described in this chapter allow a planner to maximize his or her efficiency. Using the computer to filter through thousands of alternatives allows him or her to concentrate on the advantages and disadvantages of a handful of options. This relieves much of the tedium of considering a great number of options, letting the planner focus on the alternatives that present the best "raw material" from which a completed plan can be built. The method also relieves the planner of some anxiety, knowing that what they are building has already been vetted by the public, and is more likely to be received positively.

Since the data for this study were first collected in 2010 and 2011, advances in computer technology have continued unabated. In recent years, smartphones have become inexpensive and relatively popular. These powerful, sensor-laden, GPS-enabled phones can be an effective data collection platform. While the methods that we developed are a vast improvement over those that have gone before, the ability of smartphones could potentially improve data collection by the same amount again. Potential applications range from the simple tracking of a consenting user's motion within a study area, to a more interactive application, which allows the study participant to take photographs of special places, enter text on site, and record audio annotations, sounds of the study area, and levels of ambient noise. Of course, since all of this can be geolocated, we can obtain a wealth of information in a much shorter time, while retaining the ability to extract the essence of this information for planning purposes.

It should be noted that, while the potential of smartphone applications to revolutionize qualitative and quantitative data collection is great, no technological solution is a panacea. For the next few years, a significant proportion of the population will not own a smartphone, or may own one that cannot meet the demands that the software places on it, particularly if the application is full-featured and demanding of resources. In Canada, data rates remain relatively expensive, so a fully online system may meet with resistance, particularly if no compensation is offered for smartphone data usage. Smartphones, because of their expense, also bias data input towards those who are young, technically literate and relatively well off. Thus, while a smartphone app will be an important adjunct to more pedestrian methods of collecting data, it will not be able to supplant less technically intensive means of data collection until powerful smartphones are owned by an overwhelming majority of the public.

Of course, if a smartphone-based application is developed, there is no need whatsoever to perform mapping in advance. If data for multiple users shows them congregating at a particular point, the feature can be mapped soon after the location is identified; if we have a real-time data connection, it might even be possible to map ephemeral events as they occur, providing a far superior temporal resolution in our database of features.

In this chapter, we have performed a cursory examination how periphery areas can be used to define boundaries of places, using a single variable that has been analyzed in two different ways. Many more factors can be considered in the definition of core and periphery areas; these will be explored in further detail in the next chapter.

Chapter 7: Application 2: Core and Periphery Tool

This chapter extends the work done in Chapter 6, further developing the scope and depth of analysis of places. We use ***simulated annealing*** to better characterize the subjective boundaries developed in the previous chapter. Simulated annealing is a computational intelligence technique to examine numerous options and choose the best, according to a predefined suitability function. The function, in this case, is used to optimize the shape of a core or peripheral area, so that it is acceptable to both planners and members of the public. In this procedure, four new variables are examined in addition to the number of groups of contiguous pixels (*NumRegionGroups*) that was used in the previous chapter. This method allows us to better characterize the polygons created by the procedure.

The subjective boundaries discussed in Chapter 6 were all derived from the "periphery" of the park, and in this chapter, we develop the idea of a corresponding "core." With a model developed for generating core and peripheral areas for all participants, the uses of this method for examining sub-groups (e.g. different genders and age classes) are then explored, giving a spatial dimension to their place attachment values. It is even possible to define core and peripheral areas for individuals, particularly when they define complex place attachment surfaces.

7.1 Core and Periphery in the Literature

The concept of core and periphery is an important organizational framework, one that is found extensively within and beyond geography. Frank (1996) defines the core as being the *essence* of a place, as defined by a majority of people. The periphery, on the other hand, is an area that surrounds the core, and may have been identified by one or more participants, but which lacks some of the essential elements of the core. Rarely is there a sharp divide between core and periphery; one of the key questions is where to draw the line between the two so that the difference between core and periphery is maximized. The purpose of this chapter is to develop and apply a new technique for the delineation of core and peripheral areas on fuzzy surfaces.

On many three-dimensional surfaces having a small number of peaks, the concept of "core" and "periphery" is intuitive. This has been a general theme in geographical literature for well over forty years, and it has value for generalizing and describing three-dimensional objects. When we are working with large, complex surfaces that contain many peaks and pits, the delineation of core and peripheral areas becomes much more difficult, and it is necessary to make use of computer modeling to determine the best boundary, given the nature of the data.

Although the example used here comes from research to understand the nature of place, any type of three-dimensional data set could be used, as long as the surface is the product of some sort of resource distribution. In the case of place, the resources are intangible, but the process might also be useful in the disciplines of economic geography or urban planning, where the concepts of "core" and "periphery" are less novel.

7.1.1 Modeling as a tool for evaluating place

Many of the models used in economic geography date from the early descriptive tradition in geography, in which there were many generalities, but few "rules" that led to solid predictions. The later positivist tradition, upon which quantitative geography was founded, attempted to derive general rules about the distributions of core and periphery in nations, cities and neighborhoods. Smith, Light and Roberts (1998) state, "Beginning in the 1950s, geographers struggled to eliminate these difficulties [the lack of general rules] by treating place not as actualities but as abstractions" (p. 1). A core principle of the positivist tradition is reductionism, in other words, taking a complex, real-world phenomenon, and reducing it to a single, carefully chosen indicator value. In the world before computers became ubiquitous, this was one of the few ways to understand complex phenomena scientifically. For example, the count of a particular indicator species could be used as a proxy for the overall health of an ecosystem. One of the problems with this approach is determining how to abstract a complex environment into a single variable, and how this choice can introduce bias into the modeling.

Post-positivist scholars recognize that the world is a complex place, possibly beyond the human ability to comprehend. Advances in the understanding of natural systems have come about through the development of new theoretical constructs including fractals and complexity theory (Sheppard, 2001). These new ways of understanding the world have led to a paradigm shift in geographical thought.

As we investigate more complicated problems supported by large data sets, the positivist paradigm is gradually being supplanted: "We seem, however, to have reached a point where all the simpler, more generic problems have been solved, and where what remains is a set of difficult, context-specific problems" (Goodchild, 1992, p. 37). New models of science should be able to deal with complexity effectively.

Complexity theory and fractals have helped us to understand the mechanisms of ecological systems, and the post-positivist framework is leading to the discovery of new approaches to address the challenges of complex systems, one of which is based on computer modeling.

While it may be difficult for an individual to keep track of the hundreds of key parameters that can influence the health of an ecosystem, such work can be performed using computer models. Sheppard states,

> Complexity theory... is catalyzing a revolution in the kinds of mathematical practices that are considered intellectually respectable.... A revolution in mathematical practices has begun, in which insistence on only using mathematical reasoning that results in general theorems supported by a deductive proof has been displaced by new practices that value computational and simulation strategies as highly as general proofs (Sheppard, 2001, p. 543-544).

Using a GIS, we can now create place attachment surfaces for of hundreds of study participants. We can sum the place attachment surfaces based on different criteria such as gender, age or season. Using computers, we can analyze these summed surfaces to determine which areas belong to the core and which belong to the periphery.

7.1.2 Core and Periphery

A brief review of the literature shows how these terms and their synonyms are common in many different fields including social networks (Bugatti and Everett, 2005), computer networks (Rombach, Porter, Fowler & Mucha, 2014), cognitive science (Levy, Hasson, Avidan, Hendler & Malach, 2001), medicine (Britto, Habibi, Walters, Levin, & Nadel, 1996), and history (Adolphson, Kamens & Matsumoto, 2007). Core and periphery, as well as related concepts such as "heartland and hinterland" and "center and margin," are found throughout geographical thought (Marshall, 1996).

In economic geography and related fields, the core is highly populated by humans, is economically powerful and is a strong consumer of natural resources. Marshall points out that, for economic geographers, "Core-and-periphery models are mainly concerned with areal differences in employment structure and levels of economic welfare" (Marshall, 1996, p. 303). Such models are generally applicable, and have been shown to operate at three scales.

First, at the global level, Frank's Dependency Theory (Frank, 1967) and later, Wallerstein's World Systems Theory (Hopkins, 1996) have had a strong influence over how we perceive international development, and in the latter theory, whether we classify countries as being part of the "core" or the "periphery." Here, we see the core (developed) nations with great economic power, educated populations, generally good health care, well-developed infrastructure, and strong manufacturing and technology capacity. The peripheral (lesser-developed) nations have fewer of these attributes, and the semi-peripheral (emerging) nations are rapidly acquiring many of the attributes of the developed nations.

Second, at a national level, the Von Thünen and Hall (1966) model helps to explain the development and location hierarchies of agricultural service towns. Marshall (1996) points out that, "The general concept of core-and-periphery lends itself readily to applications at different scales" (p. 304). The patterns of development are a function of travel time and resource expenditure, so this general applicability should not be surprising. Weber's theories of industrial production (Berry & Horton, 1970) and Christaller's Central Place Theory (Christaller, 1966) are complementary to the Von Thünen model. Central Place Theory models the retail sector and helps to explain why certain cities develop as service centers whereas others do not (Marshall, 1996).

All of these models feature cities and towns with core functions, surrounded by peripheral areas of lesser importance. Some cities grow in importance relative to their neighbors by virtue of their location, culture and physical attributes. Core cities have many advantages, such as an abundance of head offices, large, well-educated populations with relatively high incomes, and strong economic, transportation and communications links with other core cities and countries.

Third, within cities themselves, areas of greater or lesser influence can also be found. The Burgess model of concentric land use in North American cities (Burgess, 1925, cited in Berry & Wheeler, 2005) and Russwurm's model of the areas surrounding large cities were early attempts to explain the structure of cities (Marshall, 1996). Central Place Theory has been adapted to a variety of different scales and can explain the development of cities themselves. Berry, Horton and Abiodun (1970) argue that "…*whatever* the distribution of purchasing power (when whether in open countryside or within a large metropolis) a hierarchical spatial structure of central places supplying central goods will emerge" (p. 174). Urban geographers speak of the "city core" and contrast it with the suburbs. Marshall characterizes the urban core as being a concentrated area of population that contains a disproportionate amount of employment, banking activities and decision-making power relative to the surrounding periphery.

Montello, Goodchild, Gottsegen and Fohl (2003) discuss the use of a 50% confidence limit when they asked people to draw the downtown core of Santa Barbara, California. They found that study participants were willing to draw a line around their perceived downtown area, but that many acknowledged that there was a "semi-periphery," a zone of transition between the downtown and suburban areas. This shows that, although the urban core can be defined statistically, many people implicitly recognize that it has a fuzzy boundary.

We have seen that core and periphery can be applied at small to medium scales. With increasing amounts of data available at large scales, in particular crowdsourced geographical data, this concept can now be extended to local areas, such as neighborhoods, large institutions and public spaces.

In biogeography and tourism geography, the perspective of economic geographers is reversed, and the core is an area of many natural resources, which offers an alternative to highly populated areas. The Hooge and Eichenlaub (2000) home range tools, for example, can determine the area within which there is a 50% or 95% probability of locating a tagged animal at any time. This area is sometimes referred to as "core habitat."

In Tourism Geography, we see a similar pattern, but where natural environments are valued for human reasons. Tourists may travel to obtain a break from their everyday lives, or they may seek rest, relaxation and recuperation. Thus, tourism, like biogeography, reverses the spatial pattern that we see in the models of core and periphery used in economic geography. As Porter and Sheppard explain,

> Tourism inverts the usual logic of location theory in economic geography. Generally, in the production of an economic good, raw materials are exploited at one or more locations, transported to a place to be processed, moved to their markets and distributed to the consumers.... With tourism… the product is "finished" in its original state and marketed by shipping the consumers to the source of raw materials (Porter and Sheppard, 1998, p. 541).

Although not all tourism is to wilderness destinations, when it is, we see overlap between the biogeography and tourism geography definitions of what forms the "core" – it is an ecosystem that contains resources necessary for animal survival and it is also a place where people go for short periods to escape their ordinary lives.

We can see that core and periphery have two related, but distinct meanings in geography. Much of this difference is one of focus: in economic geography, we are primarily concerned with economic matters, whereas in tourism and biogeography, we are concerned with human well-being and the health of the environment. In the economic geography sense, the core is filled with humans, human activity and things people consider important. In the biogeographic sense, the core may be devoid of humans and human influence entirely. This is not to say that the biogeographic core is necessarily hostile to humans, only that human needs do not overwhelm other elements of the ecosystem in such places.

Thus, there is a duality between the economic geography sense of "core" and "periphery" and the biogeographic and tourism geography sense. The economic core is the biogeographic periphery, and the economic periphery may include the biogeographic core. Our society extracts resources from the economic periphery to power the economic core, but these resources are also, in many cases, essential components of the ecosystem. Those animals that are unable to tolerate human presence retreat to the biogeographic core to ensure that their own needs are met. However, if resources are extracted from the biogeographic core to power the urban core, species may be extirpated and the area may lose some of its attractiveness for tourists as a result.

In this chapter, we examine the biogeographic and tourism geography concepts of "core" and "periphery" and apply these concepts to identify the core and periphery of important places.

For people, some places, such as a person's home or place of work, may be visited daily, whereas other places, such as a local park, may be visited infrequently. Within places, there may be differing levels of visitation. Thus, we can see that even at the level of places, there can be core and peripheral areas.

People tend to inhabit one or more places in their daily lives, and occasionally visit exotic places during vacations. As Manzo (2005) put it, "… a whole array of places constitute our lifeworld and are of central importance in our lives…" (p. 69). Places can be thought of as being human habitat. According to Brown, Raymond and Corcoran, "…what is termed 'place attachment' has much in common with what biologists call a 'home range'" (Brown, Raymond and Corcoran, 2014, p. 43).

With the development of location-aware devices such as smartphones and activity trackers, there is now an abundance of local spatial data tied to individual people. What was once limited to radio-collared animals is now available to those people who are willing to track themselves. Such technology can allow for an increasing number of large-scale studies of core and periphery.

If our goal is to define the core and peripheral areas of Colliery Dam Park programmatically, then we want to identify places that fulfill the social and psychological needs of park users (Chiesura, 2004), as well as those areas of significant, but lesser importance.

Chiesura cites Coeterier *et al.* (1997), who stated that being in contact with nature was specifically evoked by landscapes featuring water, so we might expect that the water features of the park will be included in the core. Conversely, those areas of the park that feature difficult topography would tend to be part of the periphery. The peripheral areas of the park will still be used by park users, but not as frequently or as intensively as the core areas; these may include areas that are of great importance to particular users, but which are known to few or are avoided by the majority.

One issue with defining the core and peripheral areas of the park is that fuzzy surfaces resulting from data collection from park participants tend to be highly irregular in shape (Carver, *et al.*, 2009, Lowery and Morse, 2012). As with the subjective boundaries discussed in Chapter 6, many of the criteria for core and periphery areas apply here as well. The main difference is that these areas are used for geographical research, and unlike the work in the previous chapter, we are equally focused on the core and peripheral areas, rather than focusing solely on the periphery.

This leads to the following criteria for the core and peripheral areas of Colliery Dam Park:

Core

- The core will be completely enclosed by the peripheral area;
- it should have a relatively small planimetric area; and
- it will be used frequently by a majority of park users.

Periphery

- The periphery will completely enclose the core area;
- it should have a relatively large planimetric area; and
- relatively few people will access the periphery on a regular basis.

7.2 Production of Core and Peripheral Areas

The production of core and peripheral areas in this chapter is a refinement of the technique developed in Chapter 6. The intent of the work described in Chapter 6 was to create tools for planning, however those tools can be generalized and improved to provide a general platform for geographical research into place.

The previous technique used was positivistic and based on the shape of a graph of the number of region groups. The technique used in this chapter makes use of a simulated annealing process, which is a type of computational intelligence technique that produces a near-optimal solution, while allowing a wide variety of options to be explored. This approach allows the computer to navigate intelligently through the options available, while avoiding "local minima" that can trap some types of optimization techniques. The result should be core and peripheral areas that have nearly the best shape available, given the inputs.

7.2.1 Data Source

The summed surface used represents the place attachment of the 239 accepted study participants to a study area centered on Colliery Dam Park (Figure 7.1). The surface is extremely complex, since it represents the combined viewpoints of a highly diverse population of study participants. The combination of many individual fuzzy surfaces often creates complex results such as those shown in Figure 7.1 (Carver *et al.*, 2009; Lowery and Morse, 2012). Such combined results appear to have a high fractal dimension.

In Figure 7.1, the surface appears very patchy; attempting to delineate the extent of the core and periphery will therefore be difficult. Massey (1997) comments that geographers spend much time defining regions by drawing lines. With the surface shown in Figure 7.1, it is almost certain that each geographer trying to define the core or periphery would end up with a different answer.

How do we make sense of such a complex surface, and come up with core and peripheral boundaries that a majority of study participants and experts in the field would agree with? Computational intelligence techniques use "learning" methods to approach this problem by

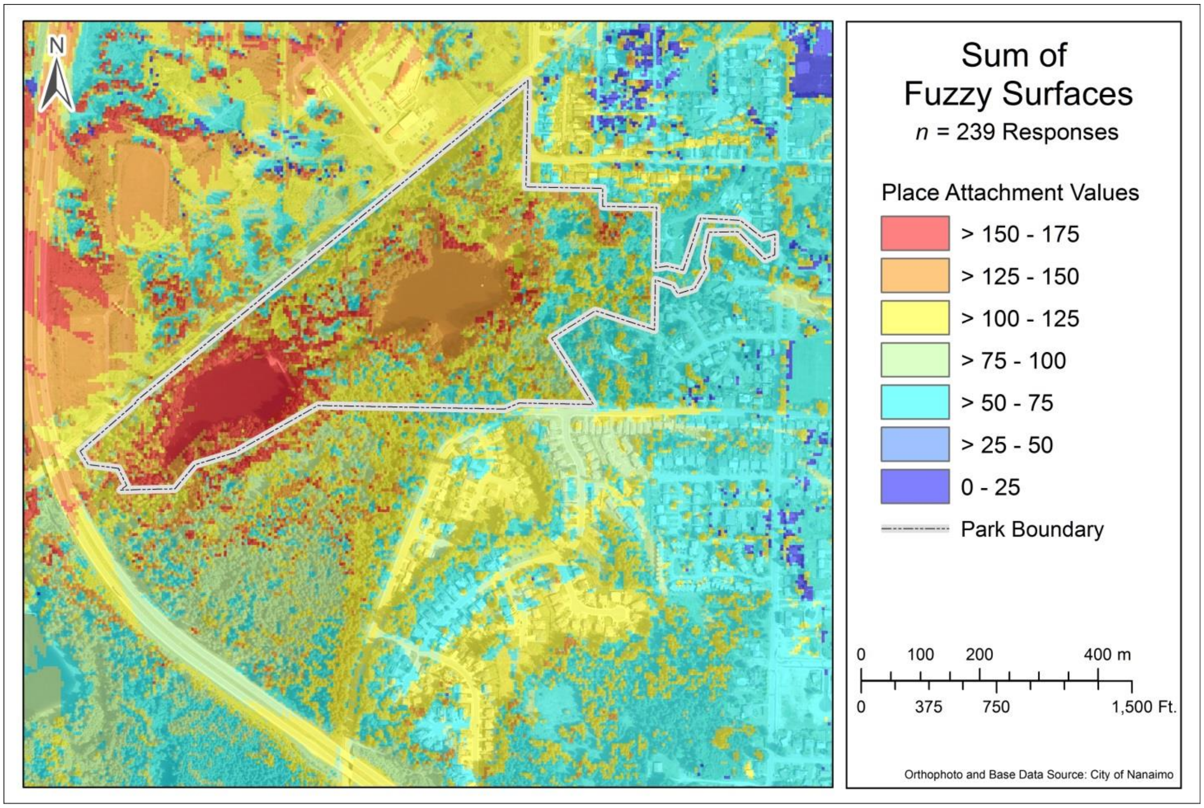


Figure 7.1. The combined surface from which the core and periphery for all participants will be determined.

replicating some of the ways that humans think. We can use such techniques to explore a large number of options, evaluating the suitability of each.

7.2.2 Core & Periphery Tool

The Core & Periphery tool (Figure 7.2) was added to the PAS to allow for the creation of near-optimal core and periphery polygons. This tool permits all participants or various subgroups of participants to be selected. The tool allows selection either by participant number or by a Structured Query Language (SQL) query, such as "*Select * from Mainform_Questionnaire WHERE: Mainform_Participant.Gender = 'M'*." From this selection, place attachment surfaces can be generated, and then these can be summed to create a single surface for analysis. This allows, for example, all valid participants, only male participants, or participants living within 1 km (0.6 mi.) of the park to be selected and analyzed.

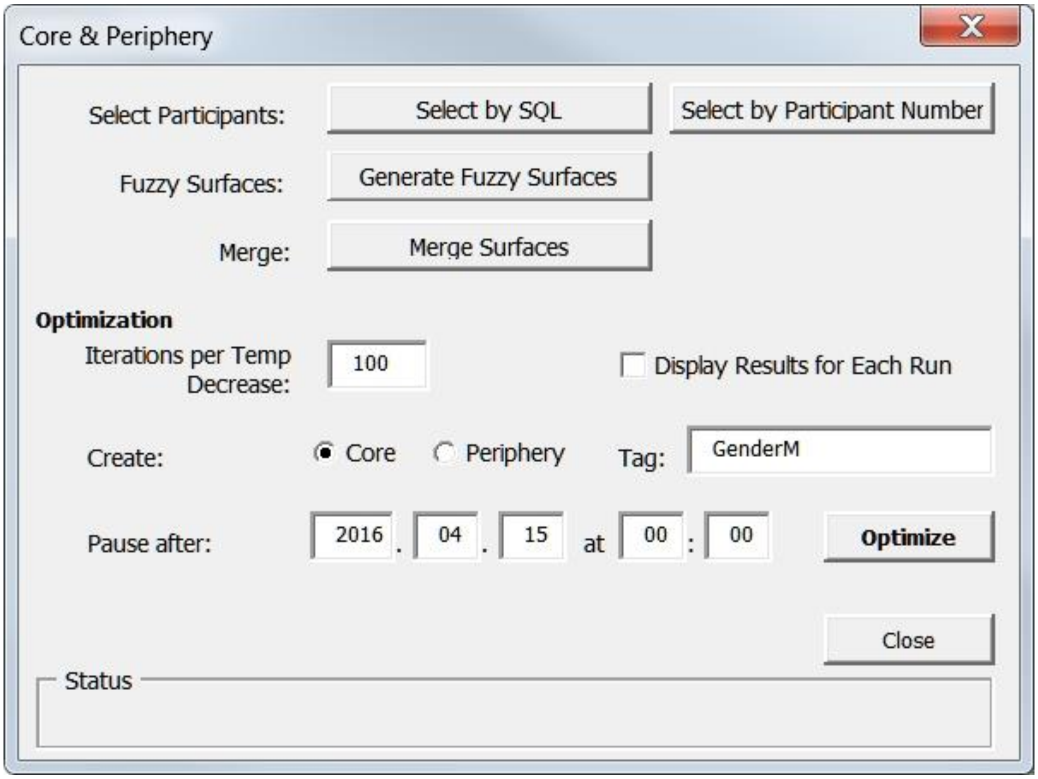


Figure 7.2. The Core & Periphery tool in the PAS permits data sets to be generated for analysis and then analyzed using a simulated annealing algorithm to produce near-optimal core and periphery polygons.

Once a surface has been created for analysis, a core or periphery polygon that most closely resembles the "ideal" shape can be created for this surface using a simulated annealing optimization routine. On the user interface shown in Figure 7.2, the number of iterations per temperature decrease (see Section 7.2.4 below), the type of polygon to be created (Core vs. Periphery), and a tag to identify the result (e.g. "GenderM") are used to control the results.

7.2.3 Calculating the Suitability Functions

The purpose of the simulated annealing optimization routine is to obtain the best possible value for both the core and the periphery suitability functions. The optimization routine chooses different α values, calculates the value of each suitability function and attempts to navigate the "problem space" to find the highest possible suitability values. The higher the suitability values, the more optimal are the shapes of the core and periphery areas chosen.

For each α value, a separate α-cut is extracted from the summed surface for the selected participants. This α-cut is analyzed to create five statistics that describe its shape. The statistics used are shown in Table 7.1.

Statistic	**Description**
NumRegionGroups	The total number of distinct contiguous areas (region groups) that are found in the α-cut. The fewer contiguous areas, the simpler the shape of the final area.
LExtArea	The total external area of the α-cut (this ignores any islands or "holes" inside contiguous areas). We want the external area to be relatively small for core areas and considerably larger for peripheral areas.
LVPARatio	The perimeter to area ratio of the vectorized α-cut areas. The closer this value is to 1, the more circular, compact, and contiguous the area is, making the area easier to understand and use.
LVNumIslands	The number of islands (or "holes") found in the vectorized α-cut area. The smaller this value is, the simpler the output area is likely to be.
LVNumPolys	The number of separate polygons found in the vectorized α-cut area. This is similar to NumRegionGroups, but the values are checked after the shapes have been refined by data processing. As with NumRegionGroups, the fewer polygons that remain, the simpler it is to understand the result.

Table 7.1. The five statistics used by the suitability functions for core and periphery. Note that the raw α-cut raster is cleaned up when it is converted to vector, so LVNumPolys only counts significant polygons whereas NumRegionGroups counts all contiguous areas in the α-cut, no matter how small.

From these five statistics, we derive two different suitability functions, one to characterize the core area, and the other to characterize the periphery. This leads to the statistics being used in different ways for each suitability function (Table 7.2).

To calculate different core and peripheral areas from the same statistics, different weights must be applied to come up with the two suitability functions. The weights in Table 7.3 were determined in advance using an empirical testing process; each weight was gradually adjusted until each suitability function produced high values for high quality areas.

Statistic	**Rationale**	**Core**	**Periphery**
NumRegion-Groups	Fewer region groups mean that the resulting shapes are easier to understand	We want fewer groups of rasters to describe a smaller, less extensive area.	We want more groups of rasters to describe a larger area.
LExtArea	A smaller external area corresponds with simpler shapes	The external area will tend to be smaller, since we want to focus on a small, well-defined area.	The external area will tend to be larger, since we want to encompass most of the existing park lots, and maybe additional areas.
LVPARatio	Lower compactness ratios mean more circular shaped, easily understood, and less likely to be disputed polygons	We want the compactness value to be close to 1, indicating that the core area is roughly circular.	We want a lower compactness value, since the peripheral area is likely to be irregular in shape.
LVNumIslands	Fewer islands mean that the shape of the core and periphery areas will be simpler in shape.	We are expecting to have few holes, since we want a cohesive, centralized region describing the core.	We are less concerned about the number of holes, since the periphery may have areas within it that are of low importance.
LVNumPolys	The fewer polygons, the easier it is to work with the result.	We are expecting a low number of polygons, typically 1, for the core region.	There may be more than one polygon making up the peripheral region; we are less concerned that the number is low.

Table 7.2: Considerations for assigning weights for core and periphery in the suitability functions. These considerations are used to help set the suitability function weights.

Statistic	**Core Weight**	**Periphery Weight**
NumRegionGroups	0.00000491	0.00005599
LExtArea	-0.00003143	0.00035429
LVPARatio	0.07827176	0.15654352
LVNumIslands	-0.002	-0.0002
LVNumPolys	-0.00017857	-0.00017857

Table 7.3. Core and peripheral weights for statistics used in the suitability functions.

By repeatedly running a series of 20-50 iterations with random values, these weights were gradually adjusted. Pairwise comparisons were used to tweak the weights, until the suitability functions produced core and periphery shapes that made sense. While we can roughly describe the values that we want for the weights based on the considerations in Table 7.2, obtaining a proper weight for each statistic was sometimes counterintuitive. The difference between a weight that produced an acceptable result and one that produced something unacceptable was sometimes very small.

It is important to note that the weights derived using the empirical process were based on the understanding of the author who is a local academic, a member of the community, and who also happens to be an expert on Colliery Dam Park. The weights were based on a limited number of trials. An enormous number of α values exist to be tested; it could take years for a human to evaluate a reasonable percentage of options. Thus, the values given in Table 7.3 are only approximate. They get us "in the ballpark," but they are not optimal weights. The simulated annealing algorithm may be able to do better using these weights, simply because it evaluates many more options.

To calculate the suitability functions, we must first convert the values in Table 7.3 into two formulae. The suitability formula for the core (S_{core}) uses the core weight values:

$$S_{core} = NumRegionGroups \times .00000491 + LExtArea \times -0.00003143 + LVPARatio \times 0.0782176 + LVNumIslands \times -0.002 + LVNumPolys \times -0.00017857 \qquad \textbf{Equation 7.1}$$

Where:

NumRegionGroups	is the number of region groups in the α-cut;
LExtArea	is the external area of all the region groups in the α-cut;
LVPARatio	is the perimeter: area ratio of the vectorized α-cut polygons;
LVNumIslands	is the number of islands (holes) in the vectorized α-cut polygons; and
LVNumPolys	is the number of polygons in the vectorized α-cut polygons.

The suitability formula for the periphery ($S_{periphery}$) uses the peripheral weight values instead:

$$S_{periphery} = NumRegionGroups \times 0.00005599 + LExtArea \times 0.00035429 + LVPARatio \times 0.15654352 + LVNumIslands \times -0.0002 + LVNumPolys \times -0.00017857 \quad \textbf{Equation 7.2}$$

Where:

NumRegionGroups	is the number of region groups in the α-cut;
LExtArea	is the external area of all the region groups in the α-cut;
LVPARatio	is the perimeter: area ratio of the vectorized α-cut polygons;
LVNumIslands	is the number of islands (holes) in the vectorized α-cut polygons; and
LVNumPolys	is the number of polygons in the vectorized α-cut polygons.

Because the weights may be negative, the summation of the terms may also be negative. To convert the values to a positive value, we calculate e^x, where x is either S_{core} or $S_{periphery}$. This returns a single value that ranges from roughly 0.3 to 1.1. A higher value indicates that the result is of higher quality.

7.2.4 Simulated Annealing Algorithm

The simulated annealing algorithm (Geltman, 2014, Kirkpatrick, Gelatt Jr. & Vecchi, 1983) makes decisions to help maximize the value of a suitability function that describes the shape of the desired output polygon. The algorithm can make thousands or millions of decisions about modifications to the input parameters, as it systematically explores the problem space.

The simulated annealing algorithm's name comes from a metalworking analogy, in which a piece of metal is heated and then cooled gradually to obtain large, strong crystals. In simulated annealing, we use the "temperature" as a control for how much variation (entropy) is allowed by a stochastic "acceptance rule." Initially, when temperatures are high, much variation is allowed by the acceptance rule, which permits a large part of the solution space to be explored, reducing the chance that the solution will be located in a local minimum. As the temperature decreases, less variation is allowed, and we converge towards an optimal solution (Geltman, 2014, Kirkpatrick *et al.*, 1983). As the temperature is reduced, the procedure keeps track of the parameters that generate the best solution.

The simulated annealing algorithm is guaranteed to converge to an optimal solution in an infinite amount of time. However the algorithm may take longer to arrive at an *optimal* solution than if a complete enumeration of all possible solutions is attempted (Kendall, 2015). Thus, we use simulated annealing to come up with a *near-optimal* solution in a reasonable amount of time, rather than to obtain the optimal solution. This is accomplished by setting a minimum temperature at which the algorithm terminates and presents the best result discovered until that point.

The algorithm uses the:

1. randomization of parameter values;
2. the creation of a candidate surface from those parameter values;
3. the calculation of statistics describing the candidate surface;
4. the use of these statistics to calculate a suitability function;
5. a stochastic acceptance rule for the suitability function values; and
6. the gradual reduction of the "temperature" until a pre-set minimum is reached

to obtain a near-optimal solution to a problem in less time than it would take to evaluate all possible alternatives.

During each temperature reduction, one parameter is modified, while the values of the others are held steady. Between 100 and 1000 iterations should be run at each temperature (Geltman, 2014), allowing the results that accrue from variations in the parameter value to be explored. The following parameters are examined:

Parameter	Description
LayerMin	The α value that is chosen. All pixels in the source raster dataset between *LayerMin* and *LayerMax*, the maximum pixel value in the input raster, are included in the subset to be analyzed. The higher the value, the smaller the proportion of the 3D surface that will be analyzed, since what is analyzed is the area between LayerMin and the maximum value in the 3D surface.
Area	The minimum size of the polygons allowed. Values may range from 0 to 50 ha. When the *Area* value is low, very few polygons will be discarded. When the value is high, polygons nearly the same size as the largest polygon will be discarded. The higher the value, the fewer polygons that will remain for analysis.
Dist	Polygons that are closer than the distance value will be merged together. The value ranges from 0-8 pixels in width (i.e. 0 – 20 m with a 2.5 m pixel size, 0 – 66 ft. with an 8.2 ft. pixel size). The higher the value of *Dist*, the fewer polygons that will remain in the output, since many will be merged together into larger polygons.
Hole	The maximum size of holes (islands) allowed in a polygon. Values can range from 0 – 10 ha (0 – 25 ac.). The higher the value, the more holes that will be present in the output polygons.

Table 7.4. Parameters used to control the generation of candidate surfaces within the simulated annealing function.

The parameters generated by the simulated annealing algorithm are used to generate a candidate surface, and then a number of statistics are calculated to describe the shape of the surface that was produced. These are passed to a suitability function that calculates the quality of the result.

Initially, an α-cut of the summed raster is created. All values between *LayerMin* (α), the minimum value selected, and *LayerMax*, the maximum value of the surface, are extracted. The *LayerMin* parameter ranges from 0.05 × *LayerMax* to 0.95 × *LayerMax*. The 5% buffer on each side is used to avoid extremely low or high values, which can cause anomalously high suitability function values for poor quality core and peripheral areas. In the first case, when *LayerMax* is too low, the entire study area is included as a single polygon, and in the second, when *LayerMax* is too high, only a few pixels are selected.

Because the place attachment surface for each participant has a range of [0,1], *LayerMax* will have a theoretical maximum of 239 (1 × n) because there were 239 participants selected. For this study, the *LayerMax* value is only 169.2, because few of the place attachment surfaces reach their theoretical maximum of 1.0.

One of the issues with the data set used is that the awareness distance around each object is uniform in all directions (isotropic). The reason for this is simply that there is insufficient evidence to support an assumption that the surfaces are anisotropic at this time. It was difficult to get people to provide a distance value let alone provide different distances in different directions. Because the park is located in a shallow river valley, it is possible that the data is anisotropic, simply because many of the trails tend to follow the contours, rather than going up or downhill. However, to model this effectively, a more efficient data collection methodology, possibly involving a smartphone application, would be required.

Because the feature surfaces are circular, features ignore natural and artificial boundaries and cross into areas such as the lakes and the Nanaimo Military Camp where people and wildlife cannot or may not travel. Lines representing barriers that hinder travel are used to break up contiguous blocks of pixels in the α-cut, so that inaccessible areas can be removed during the processing if they are too small (Figure 7.3). The α-cut is then converted to a vector layer using the ArcGIS raster to polygon command.

The **Aggregate Polygons** command (ESRI, 2017k) is run three times to filter the vector results according to the *Area*, *Dist* and *Hole* parameters provided by the simulated annealing algorithm (Figure 7.4). The reason that this is done is so that the order in which operations is performed can be controlled; the default operation of the command does not process data in the manner that we would prefer. To provide finer control, we run the command multiple

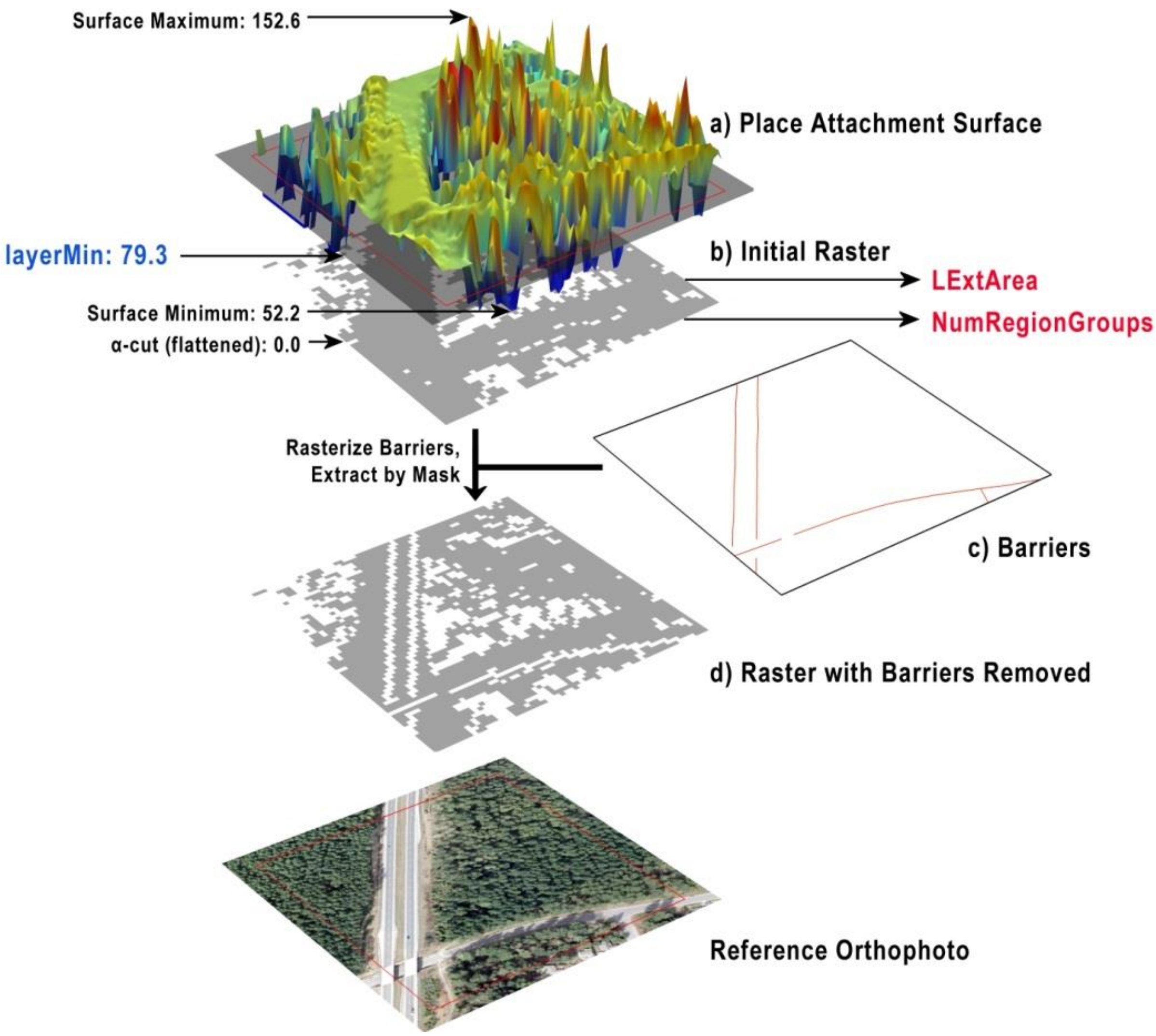


Figure 7.3. The process of creating an α-cut for the data and dividing the resulting raster with barriers. Blue values represent input parameters and red values represent output statistics. a) The place attachment surface in this 300 x 300 m (328 x 328 yd.) subset of data, which ranges from a minimum of 52.2 to a maximum of 152.6. The *LayerMin* parameter (blue) is chosen randomly by the simulated annealing process; in this case, an α-cut of 79.3 was used to define the place attachment surface. b) All parts of the place attachment surface above the *LayerMin* value are incorporated into the initial raster, which is flattened, so that all pixels have a value of 0.0. From this raster, the *LExtArea* and *NumRegionGroups* statistics (red) are calculated, so that they can be passed to the suitability function. c) The barriers have been edited to allow for overpasses and sidewalks. The barriers are converted to raster format, and then removed from the initial raster to create d) the raster with barriers removed.

times with the *Dist* and *Hole* parameters set to 0 on the first run to control the exact order in which operations are done.

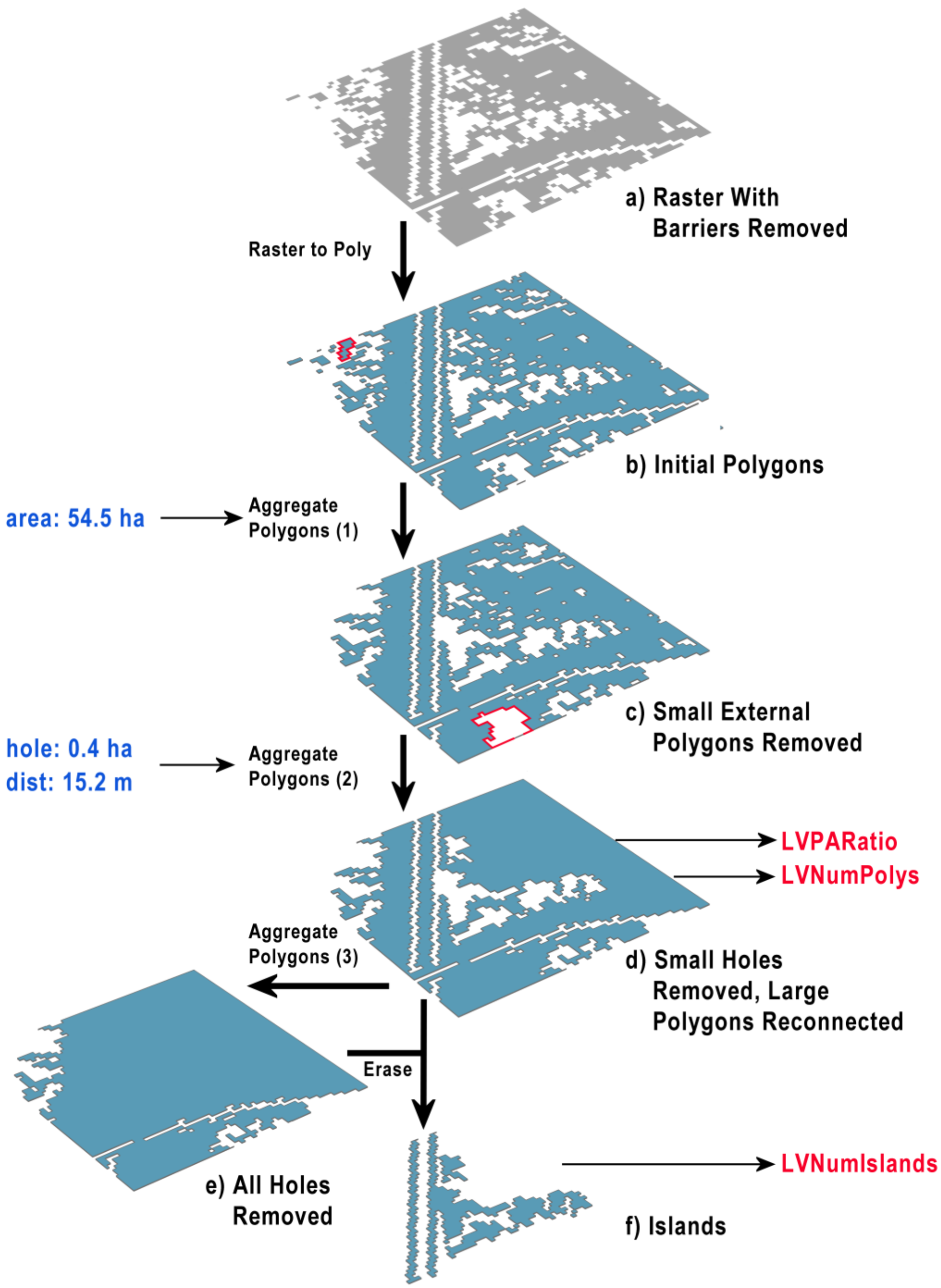


Figure 7.4. Vector processing to generate the remaining statistics for the suitability functions. All input parameters are blue and all output statistics are red. a) The α-cut with barriers removed is converted into b) a vector layer containing polygons. c) The Aggregate Polygons command is run a first time to remove all extraneous small polygons from the data set, according to the area parameter (blue). d) The Aggregate Polygons command is run again to remove small holes and to connect any remaining polygons together. The *Hole* parameter is used to set the maximum size of the holes to be removed, and the *Dist* parameter is used to determine the maximum distance that will be spanned to join polygons. The resulting data set is used to calculate the *LVPARatio* and *LVNumPolys* statistics (red) for the suitability functions. To obtain the number of holes, it is necessary to create polygons that correspond to the holes. Thus, in e) we run Aggregate Polygons a third time to remove all holes, and then we use the Erase command to erase all data except the holes from this dataset to generate f) the islands from which the *LVNumIslands* statistic (red) is calculated.

1. In the first operation, the **Aggregate Polygons** command with *Dist* and *Hole* = 0 is used to remove polygons smaller than the *Area* parameter. Because the barriers have been used to divide large polygons, many polygons outside the park area can be removed.
2. In the second operation, the remaining polygons are reconnected if they are closer together than the *Dist* parameter, and holes in the polygons smaller than the *Hole* parameter are removed. Because **Aggregate Polygons** connects polygons closer than the *Dist* parameter before removing polygons smaller than the *Area* parameter, this second step must be run separately from the first to get the desired results.
3. In the third **Aggregate Polygons** operation, *Hole* is set to a very high value so that *all* holes are removed from a copy of the data set. The ArcGIS Erase command is used to remove the result of Step 2 from the copy of the data set to create a series of polygons that have exactly the same shape as the holes in the previous step. These polygons can then be counted to obtain *LVNumIslands*, an operation that cannot be performed directly on the holes remaining after the previous operation.

To summarize, parameters are generated by the simulated annealing algorithm to create a candidate surface. Statistics are collected from both the initial raster and from the processed vector layer that is created from it. These are used to calculate the suitability function that is evaluated by the simulated annealing algorithm. The value of the suitability functions are maximized, which identifies those candidates that most closely represent either the core or the peripheral area.

The counts and areas are collected using ArcGIS internal functions; only *LVPARatio* requires significant processing within the PAS. To do this, we use the compactness function described in Equation 7.3.

$$LVPARatio = \sqrt{\frac{4a\pi}{p^2}}$$ **Equation 7.3**

Where:

LVPARatio	is the compactness of the feature;
a	is the area of the shape; and
p	is the perimeter of the shape.

This is based on a compactness function described by O'Sullivan and Unwin (2010, p. 197), which compares the area of an irregularly shaped object with the area of a circle having the same perimeter as the irregularly shaped object. A compactness index of 1 occurs only for a perfect circle; the lower the compactness value, the more irregularly shaped is the object.

Once our five statistics have been calculated, we can determine whether the α value being used has resulted in a quality core or peripheral area by applying the suitability functions that were described in Equation 7.1 and Equation 7.2.

The simulated annealing algorithm begins with a temperature of 1.0 and reduces it by multiplying the current value by the temperature multiplier, τ on each temperature iteration.[7] The τ value is usually set to 0.9, giving a logarithmic decay curve. Because this curve is asymptotic to zero, we need to set a minimum temperature value, typically 0.0001, below which the function terminates and returns the best answer that has been found.

For each temperature value calculated, a number of iterations are run, with one of the four input parameters being altered randomly while the other three are left unchanged. The input parameters were described in Table 7.4.

Geltman (2014) suggests that between 100 and 1000 iterations should be run at each temperature. At the suggested τ value of 0.9, there are 87 temperature decreases before the minimum temperature value of 0.0001 is reached, which means that there would be between 8800 and 88,000 iterations required. Fortunately, a comparison between 10 and 100 iterations per temperature decrease provides results that are quite close in appearance (Figure 7.5), so,

[7] Normally, α is used to represent the temperature multiplier, but since that variable name has already been used in the context of fuzzy logic, we will avoid confusion and use τ to represent this variable instead.

for this particular application, we can relax the minimum suggested number of 100 iterations to allow this analysis to be run on a desktop computer.

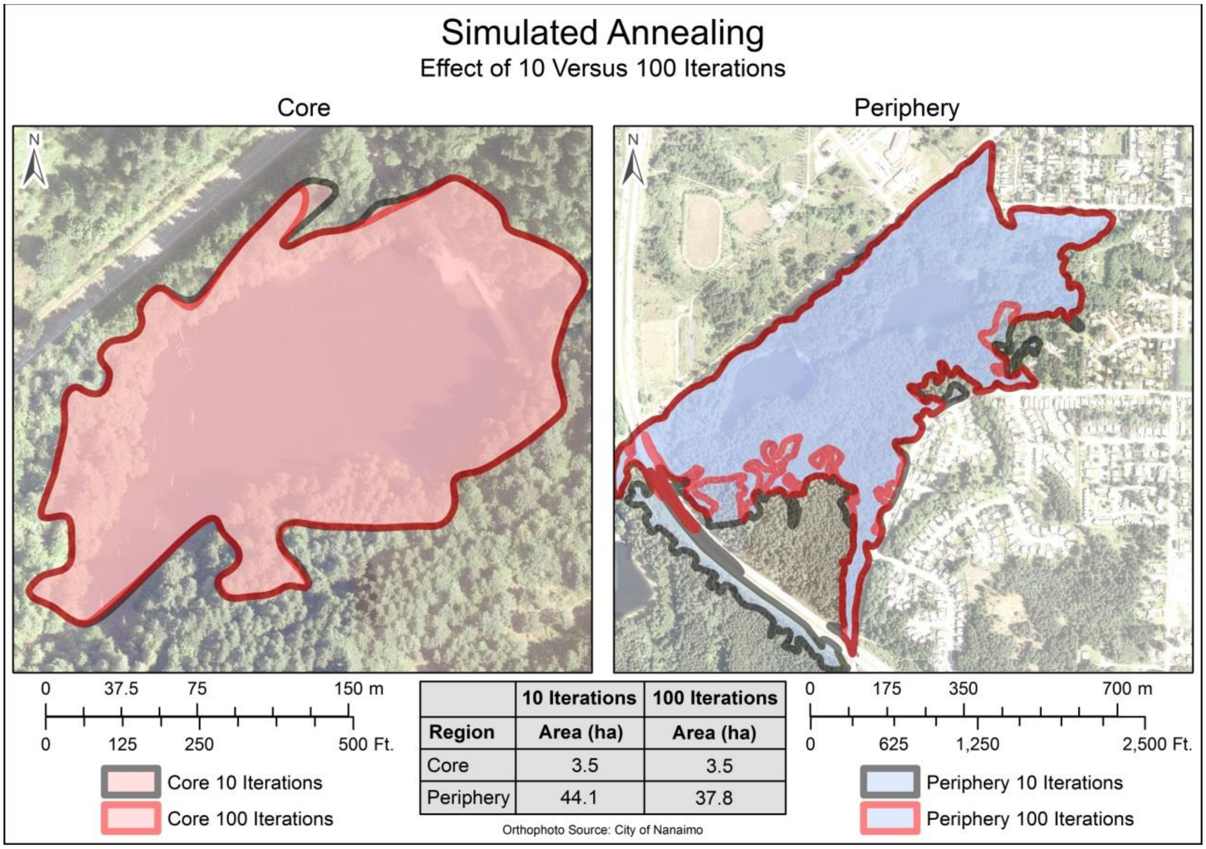


Figure 7.5. Differences between core and periphery for 10 and 100 iterations per temperature decrease. Note that the maps are at different scales and the core area surrounds the upper lake, which is in the western portion of the peripheral area.

We chose 20 iterations per temperature decrease as a compromise between the amount of processing time required and the accuracy of the results. This meant that each core or periphery polygon was generated based on 1760 iterations (which takes roughly 29 hours to process on a moderately powerful laptop computer).

The stochastic acceptance function calculates the likelihood for the acceptance of a result at the current temperature; as the temperature declines with successive iterations, the acceptance probability also declines (Equation 7.4). At a high temperature, it is relatively likely that a random result will be chosen. Thus, initially, points are chosen throughout the problem space, which ensures that a majority of the problem space is explored. As the temperature decreases, the amount of randomization decreases, and the current solution becomes increasingly fixed around a near-optimal solution. At the end of the run, when the solution is "frozen," we can be relatively confident that it is close to optimal. Most of the problem space has been explored, and the best solution within the area has been chosen. It is important to note that there is no absolute guarantee that the solution found is optimal, because the procedure cannot test the virtually infinite number of possible points in the solution space, and there may be better solutions that occupy small, unexplored portions of the solution space.

$$a = e^{(newCost - oldCost)\,/\,t}$$ **Equation 7.4**

Where:

a	is the acceptance probability;
newCost	is the more recently generated suitability function value;
oldCost	is the previously generated suitability function value; and
t	is the temperature.

Note that in Equation 7.4, as long as the *newCost* value is greater than the *oldCost* value, an acceptance probability greater than 1 will be produced, which will always exceed the random probability.

For each result, the acceptance probability is compared with a random probability value, which has a range of [0,1] (Equation 7.5). If the acceptance probability is greater than the random probability, then the new input value is stored, otherwise it is rejected. Because the acceptance probability is being compared against a random probability, even low acceptance probabilities sometimes result in a decision to accept new input values. This prevents the function from exploring only a local minimum when other nearby solutions may offer a better solution.

$$d = \begin{cases} True & if\ a > r \\ False & if\ a \leq r \end{cases}$$ **Equation 7.5**

Where:
d is the decision to retain the new input values;
a is the acceptance probability; and
r is the random probability.

Not until the temperature has declined significantly will the acceptance function be consistently low enough to "freeze" the results. Once the results are stable, it is likely that we have found an optimal result, since a majority of the surface has already been explored.

For each iteration, the values of *LayerMin*, *Area, Dist* and *Hole* are stored in a database table for later analysis. In addition, the current values of these parameters are kept in memory, and updated when new solutions are accepted by the simulated annealing algorithm. This allows the best result to be regenerated once the simulated annealing algorithm is finished.

7.2.5 Final Polygon

After the temperature has decreased below the minimum temperature threshold, causing the simulated annealing algorithm to stop, the best result is regenerated for viewing. To prevent these from having a blocky appearance caused by their origin as raster features, the ArcGIS **Smooth Polygon** command (ESRI, 2017l) is used to round the edges. This creates a better appearing result for users of the data, although small areas may be included or removed from the result during this process.

7.3 Final Core and Peripheral Areas

The findings presented below are based on the subset of study participants that were not rejected due to unusable responses (*n*=239).

7.3.1 Overall Core and Periphery

If we run the optimizations for core and periphery for all users, we find that much of the park has been included in the periphery, with the exception of some areas that are relatively inaccessible due to difficult terrain (Figure 7.6). A large area outside the park boundary has also been included in the periphery. Some of this is city-owned land, which is being considered for future park expansion (Chapter 6). The periphery overlaps a number of residential properties, particularly in the northeast part of the study area. This may be attributed to the visibility of these properties, particularly from the lower dam. Since the properties back onto the park and there is little in the way of barriers separating these properties from the park (other than those possibly built by the residents themselves), the peripheral area "overflows" into these lots. While this in no way implies that these properties should be included in the park expansion, it is interesting to note that some of the most vocal opponents of a recent proposal to remove the dams from the park live in this area, so the area of overflow may not be entirely inappropriate.

The core area of Colliery Dam Park encompasses both lakes, a majority of the off-leash dog area and the trails that circle the lakes.

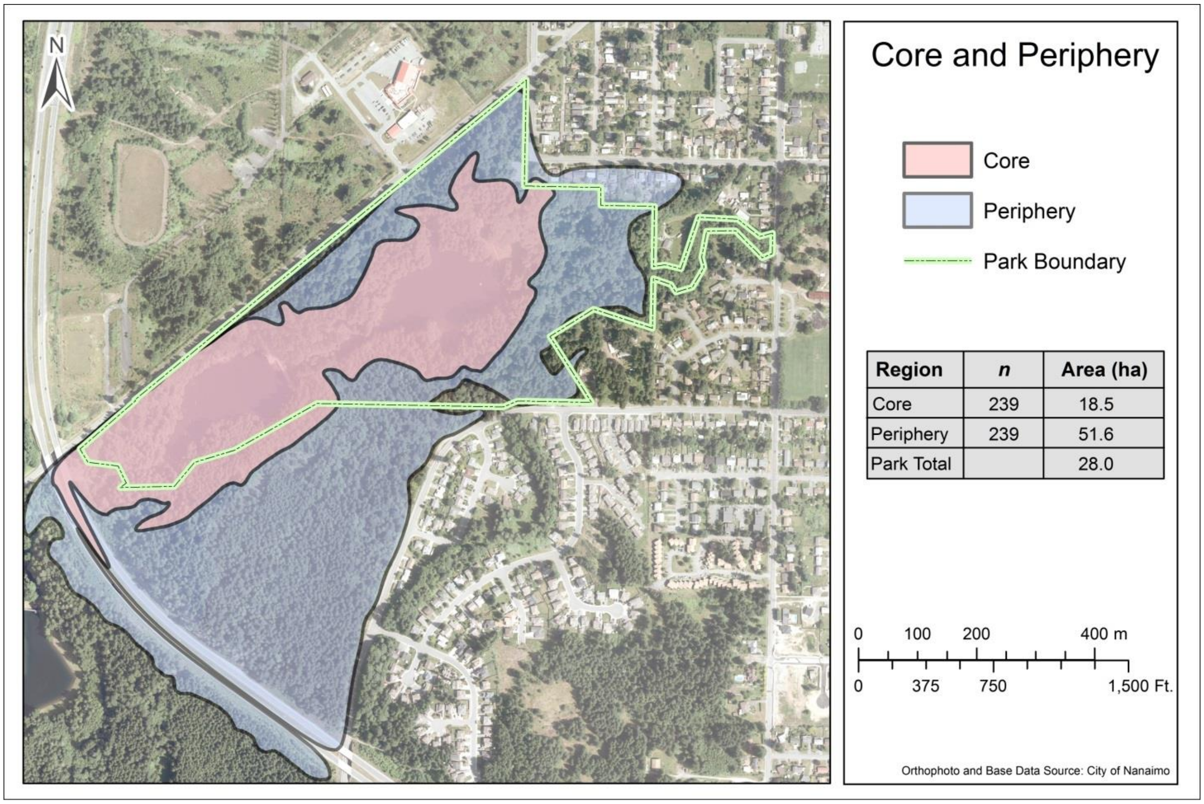


Figure 7.6. Core and periphery for all participants.

7.3.2 Core and Periphery for Different Groups

If the place attachment surface is altered to represent the summed place attachment for a specified subset of users, the resulting core and periphery outlines will reflect these changes. If we group the participants by different gender, seasons, weather, age, distance and park use, we begin to see some differences in the distribution of the core and periphery areas. These are a reflection of both the knowledge of the study participants and the freshness of their park experience.

If we break down the participants by gender, we see some interesting differences. In general, we see that the data for females shows smaller core and peripheral areas (Figure 7.7) than for males (Figure 7.8). Of particular note, the core area for females surrounds the upper lake and

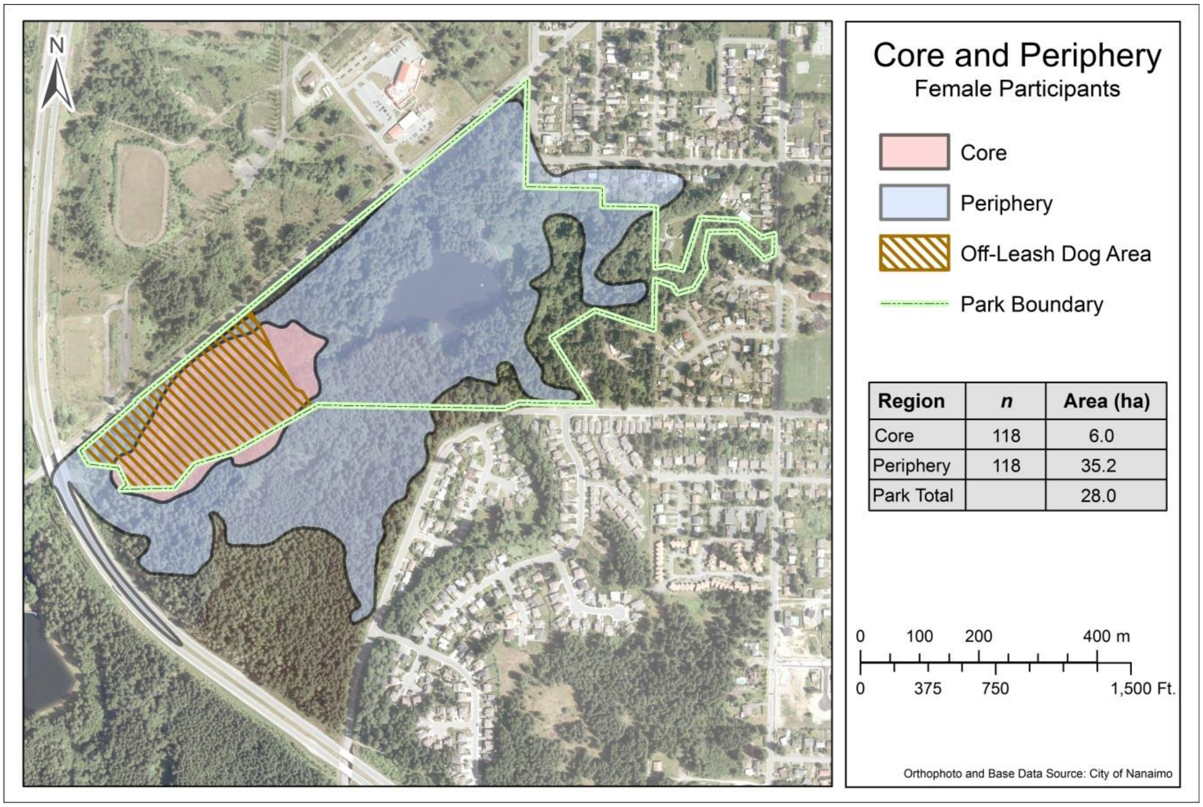


Figure 7.7. The core and peripheral areas for females surveyed.

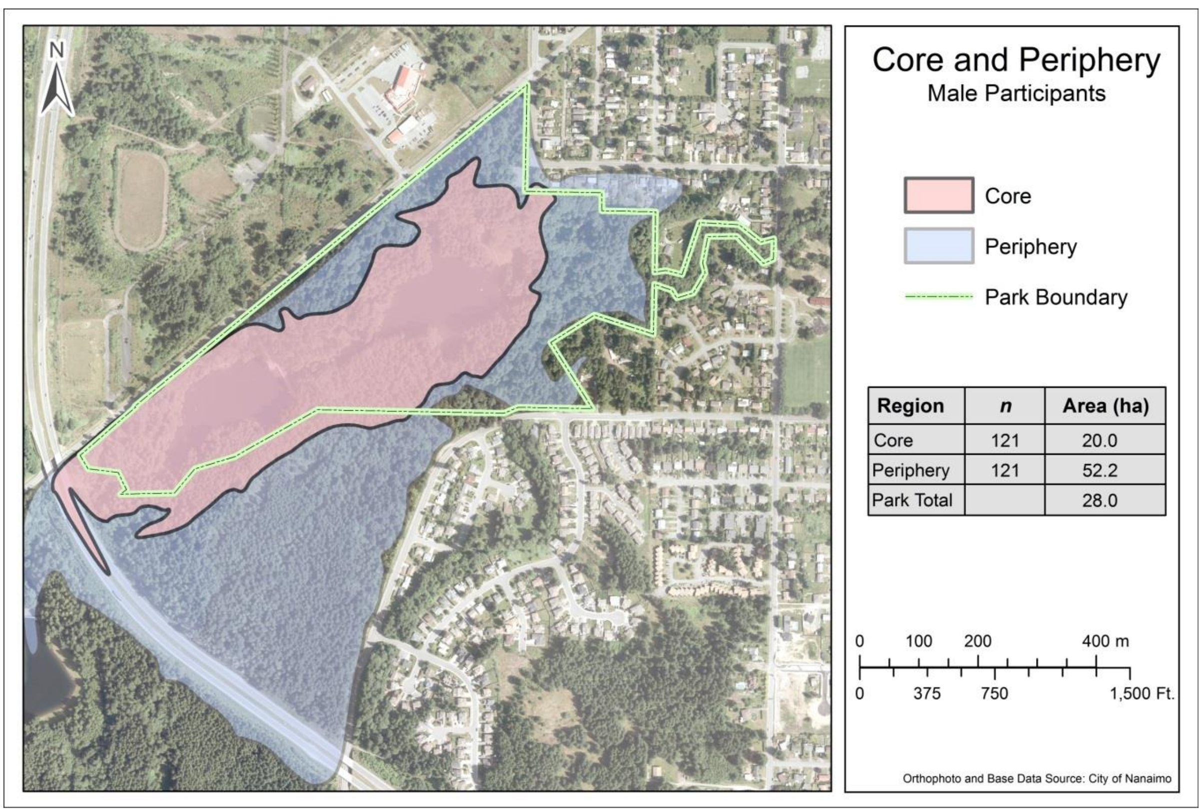
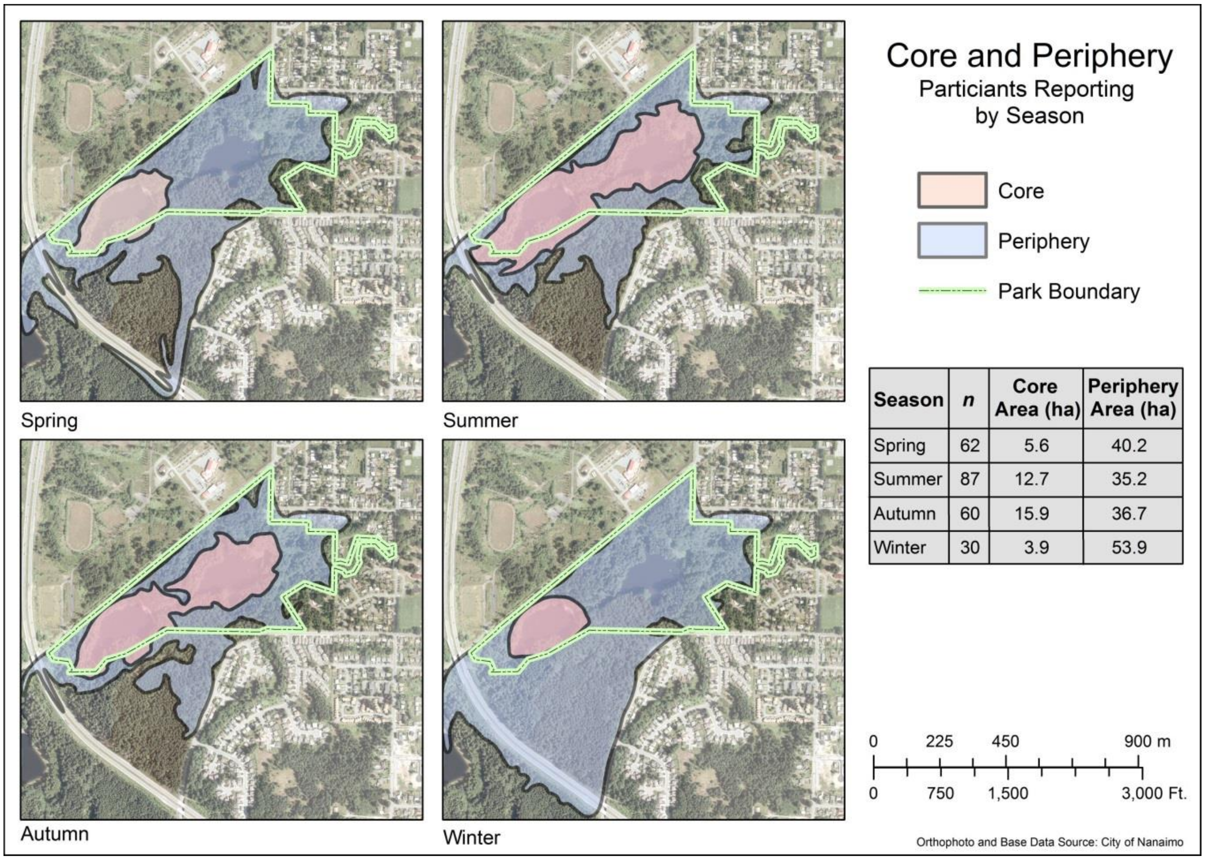


Figure 7.8. The core and peripheral areas for males surveyed.

the dog off-leash area. The peripheral areas of males and females are closer in shape, although males tend to traverse the study area more widely, particularly towards the south.

The most likely explanation for this is that 56.25% of the dog walkers that I interviewed were female, so the influence of the dog walkers within the population of females is very strong. Another possible explanation is that females felt safer when walking with dogs or were being cautious and walking only in well-traveled areas. At the time the survey was being conducted, there was a sexual predator assaulting women in Nanaimo (Bush, 2011); this might help to explain why the core area for females strongly overlaps the dog off-leash area.

Differences in core size and areas preferred during different seasons illustrate the effects of weather changes (Figure 7.9). However, the increase in the size of the core area between summer and autumn is unusual, but might be expected by a warmer than average autumn in 2012 (School-Based Weather Station Network, 2016). The periphery shrinks during the summer and expands during the autumn and winter, which is the opposite of what would be expected. The winter expansion of the periphery may be the result of the small sample size being affected by one or more outlier participants.



Season	*n*	Core Area (ha)	Periphery Area (ha)
Spring	62	5.6	40.2
Summer	87	12.7	35.2
Autumn	60	15.9	36.7
Winter	30	3.9	53.9

Figure 7.9. Core and periphery broken down by season.

Another way of dividing the seasons is to consider our climate in the Pacific Northwest as having equally long "dry" (April – September) and "wet" seasons (October – March) (Figure 7.10). While the core areas remain similar in shape, probably because of the all-weather trail system surrounding both lakes, the periphery shows a marked difference between the dry and wet seasons; this is likely due to increased wanderlust when the weather is better. It is interesting to note that even during the wet season; the waterfall just inside the western boundary of the study area is included in the periphery, implying that people may seek out the waterfall during periods of high water flow, despite the weather.

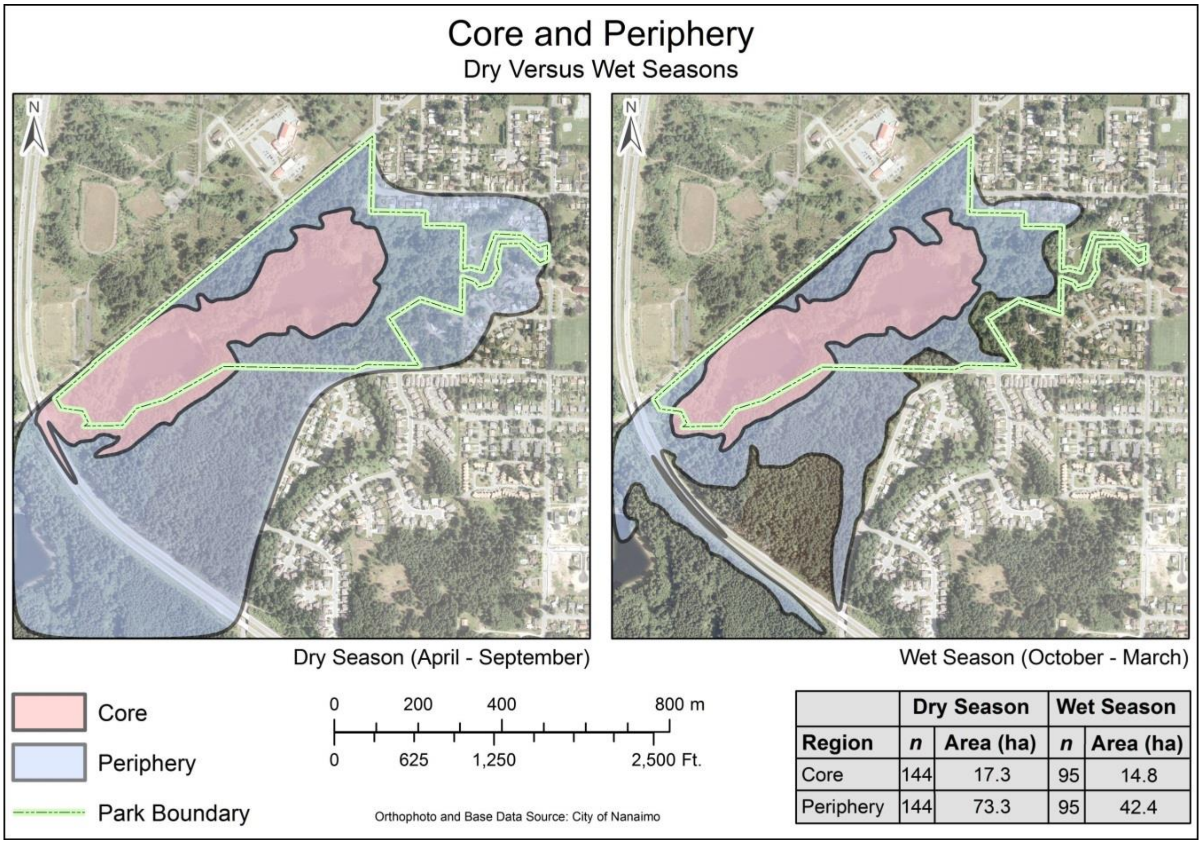
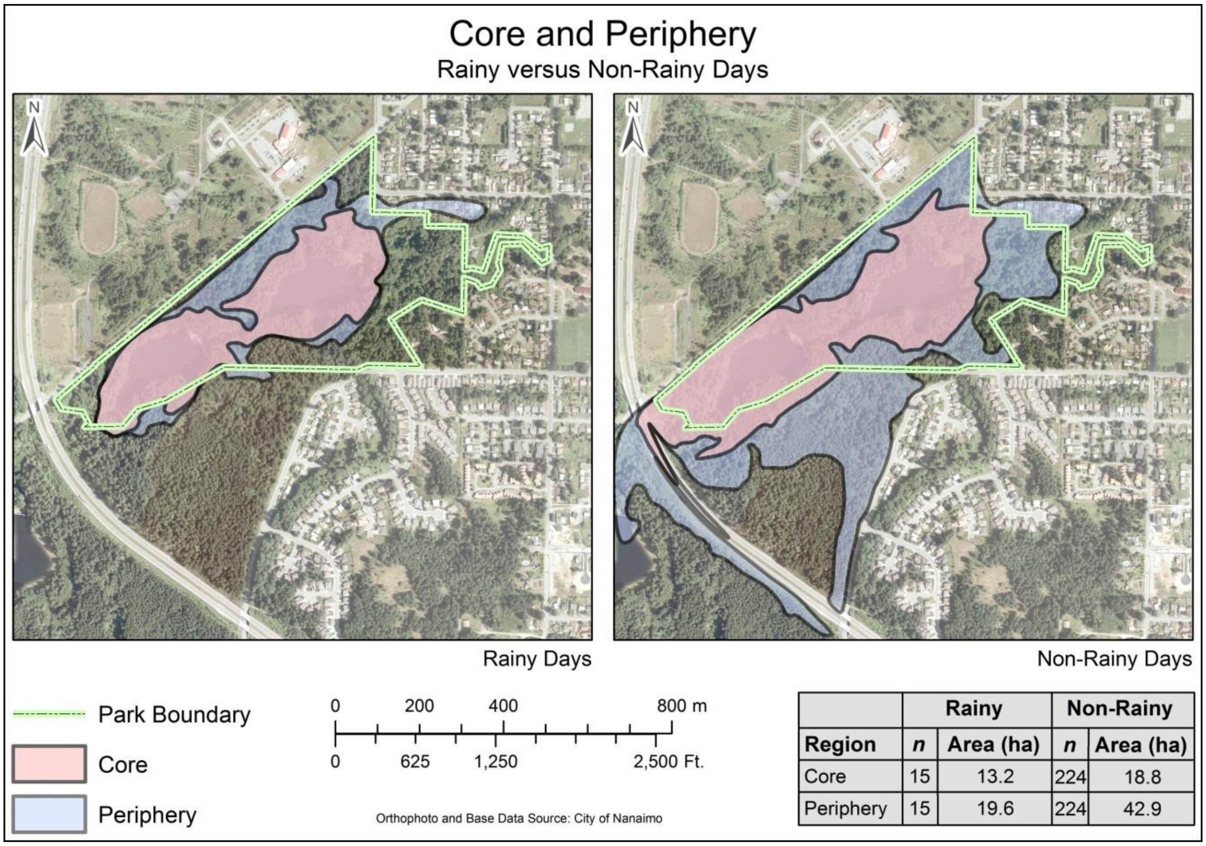


Figure 7.10. Core and periphery during the "dry" (April – September) and "wet" (October – March) seasons.

If we divide the data based on whether rain was noted on individual surveys (Figure 7.11), the difference between wet and dry is accentuated, as might be expected at a finer level of measurement (i.e. individual surveys vs. aggregated results for an entire season).

On non-rainy days, the core is similar in shape and size to what is found for the wet and dry seasons, and the periphery is nearly identical to what appears during the ***wet*** season, which is difficult to explain, unless it is simply a coincidence. Rainy days show greatly attenuated core and periphery areas, even compared with the wet season (Figure 7.10). Because the place attachment surface is based on the features that participants mentioned (and therefore recalled), the results shown are likely the result of participants not travelling widely

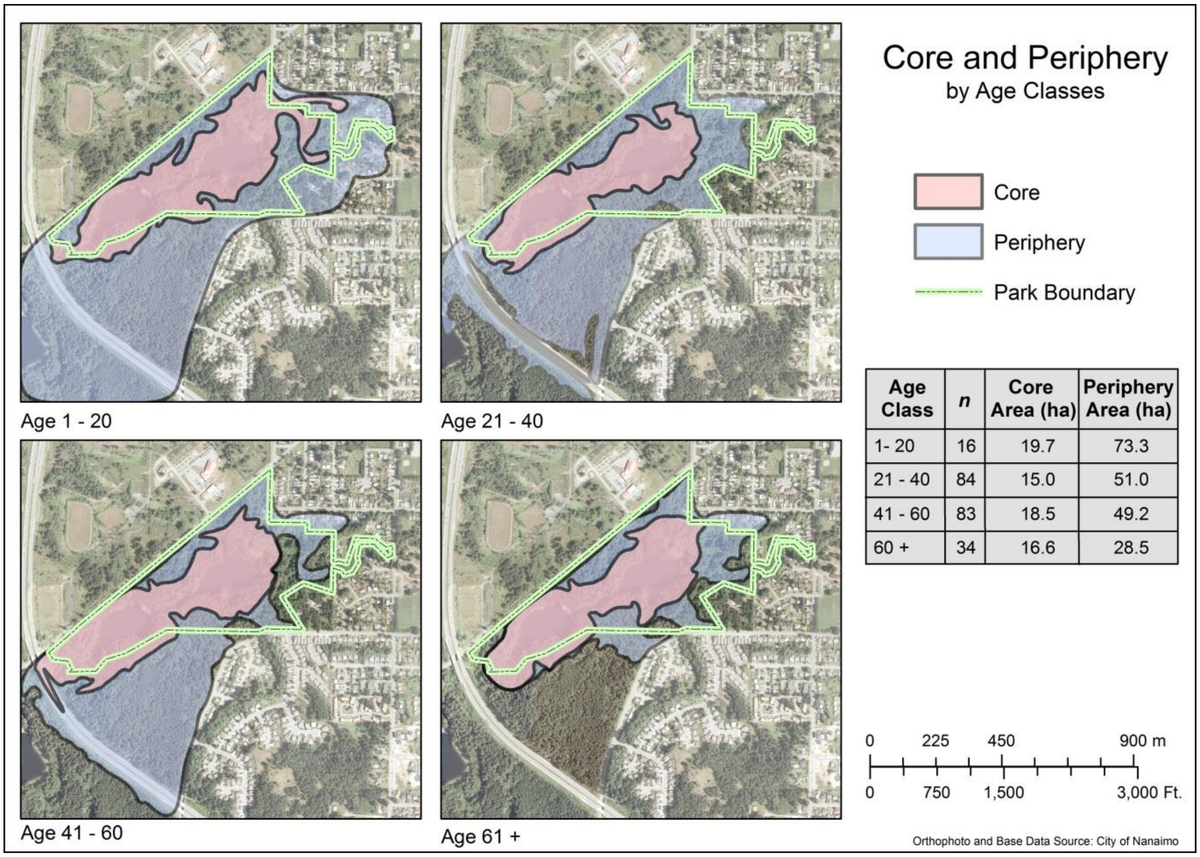


	Rainy		Non-Rainy	
Region	***n***	**Area (ha)**	***n***	**Area (ha)**
Core	15	13.2	224	18.8
Periphery	15	19.6	224	42.9

Figure 7.11. Core and periphery for rainy and non-rainy days. Note the compactness of the periphery during rainy days.

throughout the park on rainy days, and thus not being reminded of those features in the more distant parts of the park.

It might be hypothesized that as age increases, the area of the core and periphery declines as physical infirmities increase and act to limit the areas that are accessible throughout the park. Indeed, this seems to be the case when we divide the participants into 4 age classes (age 1-20, 21-40, 41-60 and 61+) (Figure 7.12). There is a downward trend in the area of the core and periphery as age classes increase, but the effect is more evident for the periphery.



Age Class	*n*	Core Area (ha)	Periphery Area (ha)
1- 20	16	19.7	73.3
21 - 40	84	15.0	51.0
41 - 60	83	18.5	49.2
60 +	34	16.6	28.5

Figure 7.12. Core and periphery by age class. While the area of the core shows a slight decline with the increase in age, the area of the periphery declines markedly. Twenty-two participants chose not to fill in their age.

The distance travelled to visit Colliery Dam Park from a participant's home affects the area of the core and periphery. As the distance from home to the park increases, the area of the core tends to decrease, while the area of the periphery tends to increase (Figure 7.13). It might be hypothesized that the core is a "well known" area, and those who live closest frequent the area they know well. For those who live farther away and presumably do not know the park as well, less preference is expressed for particular areas, and they tend to wander more widely, exploring as they go.

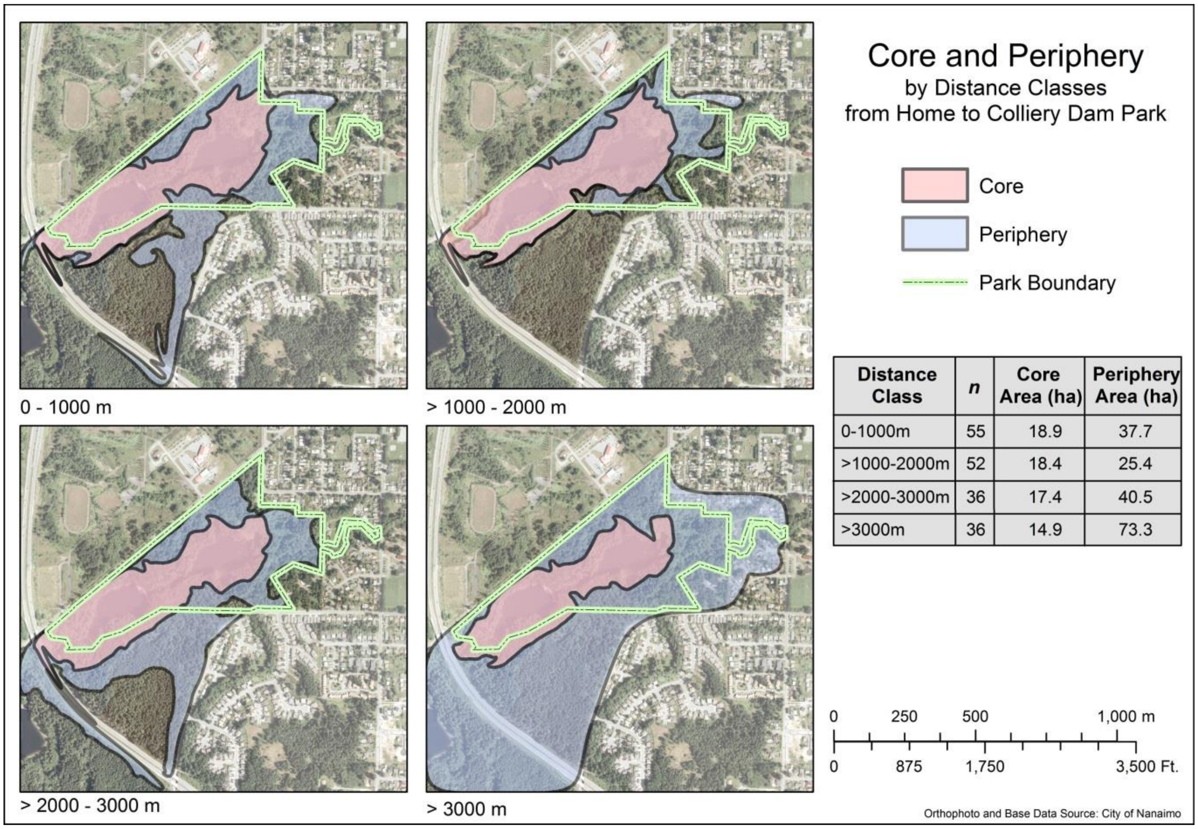
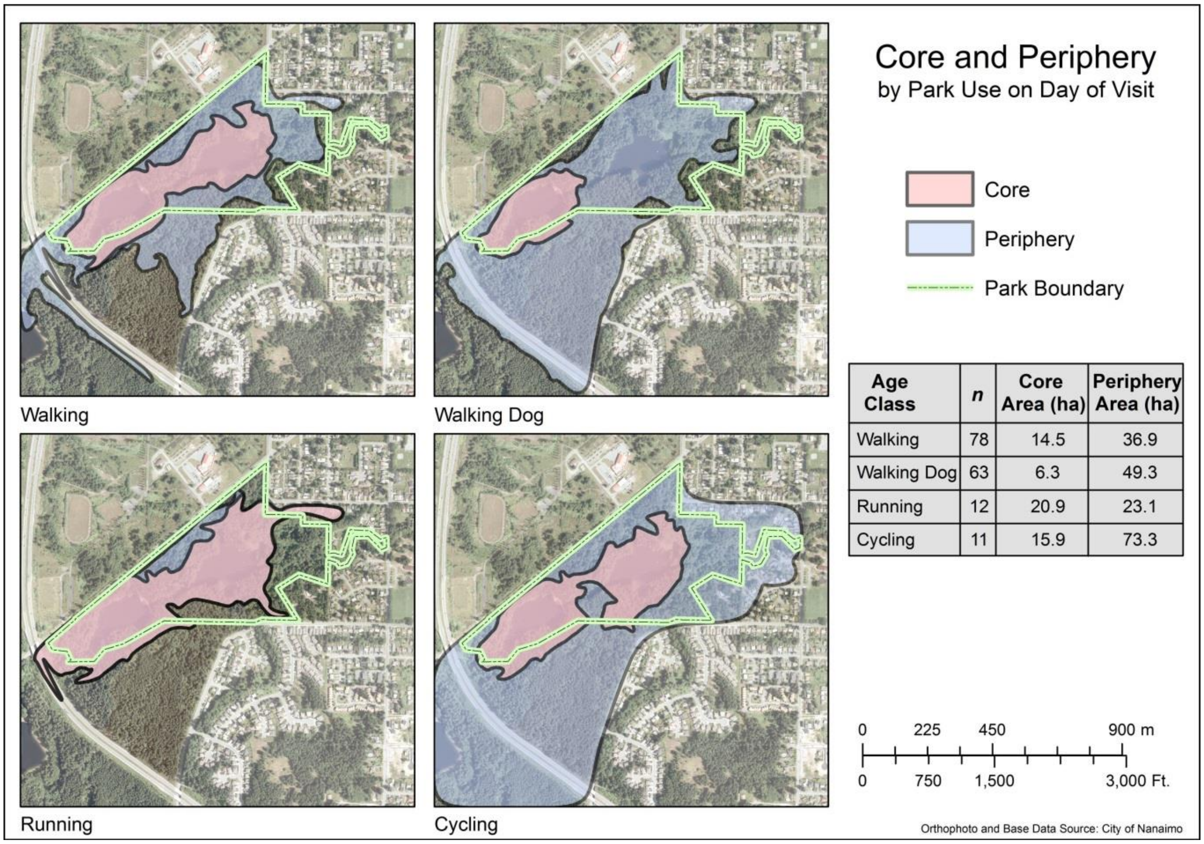


Figure 7.13. Distance classes from home to Colliery Dam Park. Increasing distance to the park corresponds with a decreased core area and an increased peripheral area.

We may hypothesize that there are distinct core and peripheral areas for different types of park users. Figure 7.14 supports this hypothesis, but caution should be employed when drawing conclusions for two reasons. First, the sample size of participants for different activities is small, particularly for running (n = 12) and cycling (n = 11). Second, it is unlikely that those participants who participated in a particular type of activity on the day that they were surveyed participate in only one activity; in other words, a "cyclist" may also run, walk and walk their dog at different times. Thus, there may be some overlap between the features described by "walkers," "dog walkers," "runners" and "cyclists."



Age Class	*n*	Core Area (ha)	Periphery Area (ha)
Walking	78	14.5	36.9
Walking Dog	63	6.3	49.3
Running	12	20.9	23.1
Cycling	11	15.9	73.3

Figure 7.14. Core and periphery for four different classes of park users (walking, walking dog, running and cycling).

Nevertheless, the core and peripheral areas expressed by different classes of park users show some notable differences. For example, the core areas for walkers, runners and cyclists mostly use the trails that surround both lakes, whereas the dog walkers frequent the dog off-leash area. The periphery for runners is very small, which is consistent with the discussion that we had with one runner, who described always following the same path through the park, rarely deviating from that route, and not even looking to one side of the trail or the other during his run. Conversely, the cyclists range all over the study area, and included the mountain bike trails on the west side of the Nanaimo Parkway. Both walkers and dog walkers mentioned a waterfall at the far western edge of the study area, but these were ignored by those park users (runners, cyclists) who moved more quickly through the park.

7.4 Implications of Core and Periphery Areas

When this chapter was outlined, it seemed like it would be a relatively simple matter to apply a simulated annealing algorithm to refine the boundaries described in Chapter 6. Since the boundaries seemed to be closely akin to the peripheral areas described in that chapter, it appeared that the extension of the concept to define the core area would make sense.

Although the simulated annealing algorithm may be a clear choice when there is a single, unambiguous solution to a problem and each calculation takes a fraction of a second, this method becomes less obvious when dealing with highly complex real-world data. In such situations, many core and periphery polygons can be argued to be "correct." They may have the same general shape, but the inclusion of a few pixels covering an area of known importance, for example the picnic area at the lower dam, can affect the quality of the output polygons. Having a panel of experts rate a number of different polygons for their core and peripheral suitability might be required to better characterize the core and periphery training areas in future.

Because each iteration takes roughly 20 seconds, it is difficult to run through the large number of iterations required by the simulated annealing algorithm in a reasonable amount of time. Increasing the number of iterations dedicated to defining each core and peripheral area would result in better outcomes, possibly reducing some of the ambiguities noted in the previous section. Improvements to the software and dedicating more computer resources are obvious solutions to this problem.

The core and peripheral areas derived from this study reflect what is known about the entire population, as well as some different groups of park users. The core and periphery polygons make sense for the overall population of participants, as they indicate that there is a strong place attachment to the lakes and dams in Colliery Dam Park. As well, we see a general interest in the officially designated park area and the adjacent city-owned lands that are now being considered for park expansion (K. MacDonald, personal communication, November 4, 2014).

The suitability function was tuned, based on the results from all 239 participants. It seems to be robust when applied to smaller subsets containing different classes of users. However, it is uncertain whether this solution is specific to Colliery Dam Park, or whether it could be applied to other areas. This will need to be investigated further using other data sets.

If the difference in gender results were the result of fear of a sexual predator by women, then it would be interesting to see whether the core and periphery patterns have changed since the capture of the offender.

The core and periphery polygons generally show the shrinkage or expansion in perception due to seasonal and weather effects, although there were some anomalies that are difficult to explain. The changes, particularly in the peripheral area during periods of poor weather, may be because visitors failed to be reminded of particular features due to constrained travel, or because they simply failed to discover new features when travel was unpleasant. The work of Lynch (1960) and Gould and White (1992) show how mental maps for poorly known areas tend to be shrunken in comparison with better known areas; the same phenomena seems to be at work here. During warmer, dryer weather, there was a general increase in the core and peripheral areas, which might be explained because people are exploring the park environment more freely.

Among the four age classes chosen, the core region was roughly equivalent in size, although it shows a slight downward trend with an increase in age. The periphery showed a marked decline in size with an increase in age, however.

The distances from the park to the participant's residence showed an interesting pattern, with a general decline in the size of the core area with increasing distance, but a trend towards an increase in the size of the peripheral area. This might be explained by users who lived close-by and tended to visit more frequently, and thus had an established set of areas that they visited. Those coming from farther afield may have been on vacation, and so had time to investigate the park more fully, a luxury not available to local residents following their daily routine.

The four park use cases shown in Figure 7.14 (walking, walking dog, running, cycling) may indicate that people who frequent the park have different perceptions of where "their" park core lies. Although the core is similar in three out of four cases (dog walking being the exception), the peripheral areas are dissimilar, reflecting the parts of the park into which users venture as they engage in their recreational activities.

Although this park contains many natural features, the dominance of the lakes shows up repeatedly in the core areas, as compared with other significant features, such as the forested areas and the trails.

7.5 Future Calculation of Core and Periphery Areas

Simulated annealing was used within ArcGIS to evaluate a spatial function. While the approach used produces results that make sense given what is known about the park, its practical application is limited by three issues.

The method of data collection used, while providing very good quality data, is tedious, involving personal surveys with participants in the field. A hybrid method, which would allow people to record their thoughts during their park visit, and then record these online, may be less difficult. Alternately, a smartphone-based application would allow park users to record their impressions and location in real-time as they travel through the park. If designed very carefully, much of the information collected using the current methodology can be preserved, and could be offset to some degree by obtaining a higher participation rate.

In this study, we employed local expert opinion regarding the location of core and peripheral areas of the park, but it is important to acknowledge that different experts may have diverging opinions. This problem might be solved by convening a group of experts (both professionals and local residents) to come up with a consensus view of where the core and periphery should lie.

A place attachment surface has value in the determination of core and peripheral areas, and using parameters related to two-dimensional shapes seems to be an effective way of processing that information via a simulated annealing algorithm, given sufficient computing resources. Some of the limitations of this method might be reduced by augmenting the information derived from features with information obtained from the positioning and travel of people throughout the study area. This would provide a separate, but complementary method of assessing core and periphery.

Given future improvements in both methodology and processing technology, determining core and peripheral areas with the assistance of a simulated annealing algorithm offers the prospect of rapidly and automatically identifying core and periphery areas. Knowing what places are of key importance to people provides a new input for planning. The core and periphery structure, which is closely related to concepts in many different disciplines, offers a unifying concept for the understanding of place in many fields, whether that place is in mapped space or some other, non-Euclidean coordinate system. While we have used the biogeography and tourism concept of core and periphery in this chapter, we might easily reverse our perspective and look at core and periphery in the more common urban planning context.

Chapter 8: Discussion

8.1 Addressing Issues of Place with the PAS

The Place Analysis System began as an elaboration of my Master's research, in which I used GIS to analyze digital terrain models to see whether landforms could be predicted based on their shape. During that research, I realized that such an application could be generalized to take any set of GIS layers that were independent variables and use these to predict the value of a dependent variable.

An obvious use of such a generalized technology would be for real estate analysis, in which both the intrinsic attributes of a property and the characteristics of its neighborhood have an effect on property values. While exploring this application and pondering the effects of neighboring lots, I began to ask myself questions such as "what makes a neighborhood distinct?" and "what makes certain places feel like 'home'?" From these ponderings, I realized that there was a much deeper question in play. The question was "What makes a place important?"

From that revelation, I began to think about how places could be analyzed using GIS and how they could be mapped, and in the process, be made real (McHaffie, 1995). While places definitely exist, people may have startlingly different views of them. It is not just the label, but the amorphous concepts associated with emotion and understanding that have real value, something called a "sense of place" by geographers or "place attachment" by psychologists.

I realized that if place attachment could be mapped effectively, it would help develop the concept significantly. Mapping makes a place real and confers legitimacy to the features that are mapped. It makes the invisible visible, allows the sense of place attachment felt by individuals to be mapped, and for those maps to be combined to understand the sense of place attachment felt by different groups. It also allows the place attachment felt by one individual or group to be compared with that felt by another.

8.2 Russell Model

Russell (2003) offers a newer model of emotions that might be better suited to place identity use in the PAS. Using Plutchik's (1980) model, place identity must be derived indirectly, through the affect values assigned to each emotion. Identifying emotions is time consuming, because there are so many of them, and the words used for the emotions are often obscure, particularly for people whose first language is not English (Appendix A). This presents a barrier for people from different cultures, and, in addition, *the emotions themselves* are sometimes culturally dependent (Russell, 2003).

In Russell's model, the concept of core affect is introduced, which is an underlying mental state that shapes people's emotions and actions (Russell, 2003). Core affect has two axes, deactivation-activation and displeasure-pleasure. Directly measuring where a participant falls on each of these axes would offer distinct improvements to the method used to collect place identity. A small number of questions could be developed to allow activation-deactivation and pleasure-displeasure to be assessed. For example, Table 8.1 shows two questions that could be adapted for a future questionnaire.

Deactivation-Activation Axis	Not at all	Unlikely	Maybe	Likely	Definitely
If this feature were threatened with destruction, would you take action to protect it?					

Displeasure-Pleasure Axis	Very Unhappy	Unhappy	Neutral	Happy	Very Happy
How do you feel you when you are next to this feature?					

Table 8.1. Example Likert scale questions to obtain information on Russell's (2003) concept of core affect, which might be useful in studies for planning.

Being able to measure activation directly provides us with a much better understanding of how likely a person is to engage in civil disobedience to protect important features. This has some important implications for helping planners gauge how controversial changes to particular areas are likely to be. Of course, with such sensitive questions, the identities of individual participants would have to be protected, but the cumulative results for large sub-groups and the entire set of participants could be very valuable for planners.

8.3 Ethical Issues

As with any technology, the PAS can be used for ill or for good. The aforementioned effects of weather conditions (see Figure 7.11, p. 205) on the peripheral areas of the park might allow an unscrupulous user of the PAS to "cherry pick" data from days when the weather is poor, thus reducing the apparent periphery area of the park. The same could be done with sample locations where the overall level of place attachment is lower. Either tactic could be used to argue that parts of the park should be removed for development. Here the need for a code of ethics on the part of the operator is clear, although it is not a panacea. Ultimately, it is the public's sense of place attachment for the park, and their ability to influence the political process that will control what changes to the park are acceptable.

8.4 Implications of the PAS

As with many technologies, the PAS stands to change the nature of place studies if it is successful and widely adopted. While such changes may modify how Geography as a discipline is performed, such changes are not all bad. It is certain that a lot of manual labor will no longer be required to perform this type of analysis, but on the other hand, there are some benefits.

For example, the extensive nature of this type of analysis, as Lynch (1960) famously noted, means that these types of studies are done infrequently because of the resources required. Making this procedure easier allows for a greater number of analyses to be performed and more comparative studies to be made, helping geographers to obtain a better understanding of how places work.

The PAS also provides geographers with a new, exciting tool that will help them gain greater respect from those in other disciplines, particularly those that are inclined to minimize the importance of the study of spatial phenomena. Rather than spending a majority of their time collecting and organizing data, geographers may be able to focus more on the analysis of spatial data, thus advancing the discipline. As with spreadsheet software, GIS and qualitative analysis software, this is another part of the geographer's toolkit.

Chapter 9: Conclusion

This dissertation began with the simple idea of asking people about their thoughts and perceptions of features in an important place and using these to construct a three-dimensional visualization of the place to make their perceptions measurable and amenable to analysis. It grew greatly in scope as the details of the study area, methodology and applications were explored.

In this chapter, we look forward to where the PAS might take us in future. It is both a blessing and a curse that this line of enquiry, which started with a simple idea, has bloomed into a multidisciplinary line of research that is difficult for a single researcher to follow. It is now time to regroup and look back at the challenges and successes of the *PlaceInGIS* project. The PAS, as the means by which this research was conducted, needs to be reviewed and prepared for its next stage of development.

9.1 Addressing Research Questions

In Section 1.9, five research questions were proposed which we have addressed as part of this research. This section summarizes the answers to each question, then addresses what parts of our overall framing question "What makes place important?" have been answered.

We have found that it is possible to take emotional concepts and to quantify them. To do this, we used Plutchik's (1980) psychoevolutionary model of the emotions, which combined 118 different emotional concepts and assigned an affect (emotional intensity) value to each. Other emotional models exist, and we may consider switching to one that offers fewer emotions (easier for participants to understand) and valenced emotional intensities (to allow for negative emotional reactions) in future version of the PAS.

How can we reconcile the emotional and cognitive components of place attachment? Williams and Vaske (2003) elaborated on Steadman's (2002) work to divide the place attachment model into place identity and place dependence. Since place identity is an emotional concept and place dependence is a logical concept, these different epistemologies prevent us from providing different weights to the values and combining them into a single concept. However, we are able to treat them as separate but equal concepts (Williams, 2016), such that the measure of place attachment is composed of equally valued emotional and logical concepts.

How do we map people's understanding of place effectively? Mapping people's place attachment is a challenge if we treat an area as a unified whole. Approached from this perspective, there are two options. We can use sketch maps, which are inaccurate representations of place or we can use existing cadastral boundaries, which are accurate, but do not represent subjective boundaries. The solution is to break down places into their individual components, a task that is virtually impossible without using some form of GIS to keep track of individual features. By asking participants about the individual features that are important to them in a place, we break down this problem into two important parts. The first is how to accurately map place attachment. If the features are mapped prior to the commencement of the survey, then places based on them will also be accurately mapped. The second is that we avoid the trap of having to choose between two mutually exclusive representations of place. We use individual features to resolve detail within the place under study and do not force participants to work with the legal boundaries of a place. In this way, a place can take on new meaning because it will feature differing degrees of place attachment within it, variable boundaries defined by the participant, and even boundaries that change over time in response to internal and external changes. Now, we are not just mapping places, but the interactions between people and places. For the first time, we can map place as a process, rather than as an object.

Unifying information for many features into an overall representation of place presented some challenges. First, we had to model how place attachment decreases with distance. Although there are many different methods of interpolation available in GIS, most of these are based on a generic view of data. None models the decay of emotions with distance. To solve this, we designed a new theory-based interpolation method, based on the work of Dornič (1967). This model uses a logarithmic decay, so that the minimum value of the surface produced is asymptotic to 0. This supports the work of many researchers who argue in favor of the *demos* model of place (Pred, 1984; Thrift, 1994; Massey, 1997; Williams, 2014) which conceptualizes place as a dynamic entity that is connected with the outside world. Using such a model, we can create a feature surface for each feature mentioned by a participant.

Next, we needed to unify the feature surfaces into a place attachment surface for each participant. In this case, we approached the problem from a planning perspective to ask, "What is the most important feature in an area, and how far does its influence extend?" If place attachment for a particular feature is very strong, then it is more likely that participants will rush to its defense, since part of the model is based on place affect, the likelihood that a person will act on their emotional reactions. Thus, we want to know what features have the strongest attachment in a particular area, and which features are of lesser importance. This can be modelled using the Fuzzy OR function, which takes the maximum value encountered in an area, creating a single surface of the highest values taken from all the feature surfaces. This function lets us combine the feature surfaces into a place attachment surface to represent the entire place with all its internal complexity.

We also needed to learn how to deal with multiple study participants, combining their place attachment surfaces for study in a meaningful way. Once we have created a place attachment surface for each participant, we are able to combine them, since all are accurately tied to their correct locations on the Earth's surface, because they were constructed from previously mapped features. To ensure that the analysis preserves the democratic underpinnings of this project, each place attachment surface is treated equally, and the results are simply summed to come up with an overall result that reflects the contributions of all participants.

When I began this research, I started by asking the question "What makes place important?" We know some of the answers, such as that places become a part of a person's biography over time, and that people identify themselves as belonging to, or being part of a particular place. Place dependence shows us that important places supply non-consumptive and renewable resources. For example, Colliery Dam Park provides places to swim and supplies of food, such as berries and fruit. It also provides important psychological benefits such as quiet and a release from the stresses of life. It makes sense that Colliery Dam Park is so prized by local residents, given all that it offers.

However, many questions remain about what makes places important. For some of these, the PAS can offer answers. In the case of Colliery Dam Park, we might ask what is the single most important feature, and how important is it?

In terms of numbers, the Canyon Bridge, located near the eastern edge of the dog off-leash area, was referenced 162 times, frequently as part of the trail encircling the dog off-leash area. The Upper Bridge, which crosses the Upper Colliery Dam and completes the trail around the off-leash area, is the second-most referenced area, with 156 references. Following closely behind is the Lower Bridge, which crosses the Lower Colliery Dam, with 153 references. Perhaps is should not be surprising that bridges form 4 of the top 10 features referenced (the other bridge completes the loop around the Lower Colliery Lake), since these are choke points over which people must pass if they wish to use the major trails in the park. The remaining features in the top 10 are parts of the trail system, including sections of the boardwalk on Upper Colliery Lake, and portions of the Nanaimo Parkway trail (Table 9.1). The trail system is so dominant that the top 58 features are part of it, and it is not until the 59^{th} most popular feature that we encounter the Lower Colliery Lake, with 127 references. The 90^{th} most popular feature is the Upper Colliery Lake, with 116 references.

A similar pattern can be seen when we look at the sum of place attachments for each individual feature. We see the same features in the top seven places, with different trails replacing the Nanaimo Parkway Trail in positions 8, 9 and 10.

If we order by the mean of the place attachment values, number of features that were extremely important to one or two participants can be seen. These include a pool on the Chase River that was once used by First Nations people for ritual cleansing (2 mentions), a

Number of References	Feature_ID	Official Name	Layer
162	3200233	Canyon Bridge	Trails_Lines
156	3200231	Upper Bridge	Trails_Lines
153	3200148	Lower Bridge	Trails_Lines
146	3200092	Boardwalk	Trails_Lines
145	3200082	Boardwalk	Trails_Lines
145	3200088	Boardwalk	Trails_Lines
141	3200182	Bridge	Trails_Lines
138	3200150	Parkway Trail - Mid Section Between Lower Parking Lot and Lower Bridge	Trails_Lines
138	3200154	Parkway Trail - Mid Section Between Lower Parking Lot and Lower Bridge	Trails_Lines
138	3200118	Parkway Trail - Mid Section between Lower Bridge and Parkway Trail Intersection	Trails_Lines

Table 9.1. Top 10 features by the number of times they were referred to by study participants.

large wildlife tree (1 mention), a stop sign (representing the halfway mark of the participant's exercise routine), and an infestation of English Ivy (*Hedera helix*), an invasive species (1 mention) (Table 9.2).

Mean Place Attachment	Feature_ID	Number of References	Official Name	Layer
11.8611	1400052	2	Pool Downstream of Canyon Bridge (FN Cultural Significance)	Historical_Points
11.7444	1900003	1	Wildlife Tree	Natural_Features_Points
11.7444	2700014	1	Sign - Stop	Signs_Points
11.7444	2700016	1	Sign Post - Parkway Trail	Signs_Points
11.7444	2700018	1	Sign Post	Signs_Points
11.3556	3800001	1	English Ivy Infestation	Invasive_Areas
11.3556	3800002	1	English Ivy Infestation	Invasive_Areas
11.3556	3800003	1	English Ivy Infestation	Invasive_Areas
11.3556	3800004	1	English Ivy Infestation	Invasive_Areas
11.3556	3900001	1	English Ivy Infestation	Invasive_Points

Table 9.2. Top 10 features by mean place attachment values.

Clearly, it is easy for a single feature to be highly ranked when it is mentioned by only one or two participants; when features are mentioned by more participants, the law of averages comes into play, and it is difficult for features to be very highly rated. However, the ability of a single individual to convince others of the importance of a feature that they consider "sacred" should not be discounted.

These results are somewhat surprising, given the general high opinion that many participants expressed for the lakes, and the resulting dominance of the lakes in the "core" areas of the park for different groups. In part, this may be the result of the law of averages coming into play, since the lakes are not everybody's absolute favorite feature, but are mentioned by many participants. In part, it may be due to the methodology, since every time a participant mentions the "trails" with no further elaboration, all trails (including all of the bridges) were included.

9.2 Challenges and Limitations

As with any large undertaking, PlaceInGIS has had both successes and failures. This project was undertaken with confidence in my ability to complete it, and, while the overall goals and methodology were complete when the research commenced, there were nevertheless large areas in the research outline that might have been labelled "terra incognita."

The PAS, as designed, has much strength, but a few weaknesses have also become apparent. Most of these are related to the data collection methodology, which was affected by a lack of survey experience and limited knowledge of place attachment theory when the survey was designed. Thus, some aspects of survey and methodology were naïve, but others were innovative.

Conducting the survey was a great learning experience, leading to a better understanding of what does and does not work when conducting data collection *in-situ*. In future, the questionnaire would be streamlined somewhat, but most importantly, the questions asked would lead more directly to an assessment of place attachment than the current method, which is somewhat indirect, and therefore less precise than it could be.

Given that the initial spatial data collection and survey were some of the most time consuming elements of the project, taking roughly 13 months in total, an improved sampling procedure would make subsequent analyses of places using the PAS more practical.[8] The adoption of a rapid appraisal methodology (Carver, *et al.*, 2009; Gunderson & Watson, 2007) and snowball sampling methods (Lowery & Morse, 2012) promise to make future sampling and preparation of the database of features more efficient. While a rapid appraisal methodology was of limited use for the Colliery Dam Park study area, which we knew well, it would be more advantageous in other areas that were less well known.[9]

For planning purposes, it would be valuable to have some understanding of whether changes to a particular place are likely to generate protests or civil disobedience. The current method of working from importance and affect to place attachment, then determining which areas are

[8]It should be noted that we commenced data collection with semi-functional data collection tool and analysis software that was still being developed; subsequent application of the PAS would benefit from the years of software development that have taken place since 2011.
[9] For Colliery Dam Park, years of experience in the park somewhat offset the limitations of the initial sampling methodology. Even so, there were features (the "hidden" waterfall and many of the culturally modified trees) that were unknown when data collection began. A rapid appraisal methodology would probably have highlighted these missing features.

valuable to people, is somewhat indirect from a planning perspective. If this work were to be done purely for planning purposes, then it might be better to introduce Russell's concept of "core affect" and proceed with a series of questions based on the deactivation-activation axis and the displeasure-pleasure axis (Russell, 2003), as discussed in Chapter 8.

Another role for the public and other local experts would be to define ideal core and periphery areas for the model. Using a simple sketch mapping process, we could obtain a number of examples of where the core and periphery boundaries lie, and these could be averaged to come up with "prototype" core and periphery areas. Once we have these, we could run an optimization program to tweak the weights shown in Table 7.3, until the weights define shapes that are as close as possible to the prototype core and periphery areas.

Having the method for calculating individual feature surfaces, choosing the formula was another challenge. Here, some basic research about place proved helpful, such as Massey's (1997) observation that places were dependent on influences that could extend worldwide. This was supported by earlier psychological research into the extent of memory by Dornič (1967), showing that memory of a place follows a logarithmic curve, so it is asymptotic and can never reach zero.

With an established methodology to create feature surfaces, the next obstacle was to learn how to combine individual feature surfaces into a single place attachment surface for each study participant. The work of Leung (1987) assisted greatly in this, because he solved virtually the same problem for climatic regions of Taiwan by using the Fuzzy OR function to merge adjoining fuzzy regions.

Next, we needed to combine the place attachment surfaces to obtain an overall understanding of how place attachment varies, and to determine what areas are most and least important to survey participants. However, the question of how to combine the place attachment surfaces for a group of people remained unsolved. The use of different fuzzy operators was rejected because they did not reflect the contributions of all participants, a key goal if the "democratic" nature of this project was going to be met. With functions such as the Fuzzy OR or the Fuzzy AND, either the opinion of the person who least valued a particular area or the opinion of the person who most valued an area was promoted, to the exclusion of all other views. To avoid this issue, we simply decided to sum the surfaces and normalize them, which took into account the views of all participants in coming up with a surface for the group.

Because Colliery Dam Park was a safe space, loved by most, if not all of its users, the Place Analysis System was molded by the park environment. The main effect was that limitations of the emotional model used did not become apparent until late in the analysis phase. The model used only featured emotional intensities, not emotional valences. Negative emotions (e.g. disgust) did not have negative values; only the magnitude of the emotion was modelled. In such a positive environment, this did not pose an obvious problem, because very few users expressed any negative emotions, but if we are to use the PAS in less overwhelmingly positive environments, we want to be able to model both positive and negative emotions and their magnitudes. Furthermore, when combining the place attachment surfaces provided by different users, we will need to model not only the mean place attachment value, but also the extremes, perhaps in the form of having minimum, mean and maximum surfaces or the first quartile, mean and third quartile surfaces. In doing this, the volume of the surface (based on the variability of responses) becomes a new, important factor that can be analyzed.

9.3 Successes

Given that there are roughly 25,000 lines of code involved in the PAS, the risk of a software error is significant. To a large degree, frequent testing of the software during the development process ensured that each step was thoroughly reviewed, but this method of development cannot prevent every possible error, particularly logical errors on the part of the programmer. Although correlation techniques discussed in Chapter 5 do not "prove" that the transformation from each surface type to the next is correct, they support our contention that that the conclusions drawn in this dissertation rest upon a firm foundation.

We can now take people's vague concepts of sense of place, and make them concrete and visible. Comparing place attachments without visualizations is like comparing the shapes of two different clouds on a summer's day using words alone. Even if analysis were not possible, a visualization of a concept as nebulous as a person's sense of place would be an important advancement as it encourages conversation about specific differences in each person's sense of place.

Because the place attachment surfaces are based on models of how emotions decay with distance and are based on precisely geolocated features, we can make meaningful comparisons between the submissions of different participants using a GIS. We can do this for individual users by simply subtracting one surface from another to look at the areas of difference, as we demonstrated in Chapter 4. This can be a valuable tool, when, for example, neighbours disagree about how each other's lots are being managed.

The summed feature surfaces, once created, were analyzed to look for spatial patterns. What was surprising about this was that the patterns of core and periphery for different groups made logical sense. In a planning context, we could see that the park was generally valued within its legal boundaries, with the exception of a number of areas that were difficult to access due to steep slopes or difficult surface conditions. The core and periphery areas, although derived algorithmically, made logical sense. The analysis showed that there were notable differences in the core and periphery areas derived for different demographic groups, activities, seasons and weather conditions.

Although it is tempting to say that we have merely demonstrated the obvious, it is important to remember that these results were generated by a computer algorithm. Tuning parameters for the algorithm were only defined for the entire group of study participants; the fact that patterns for subgroups of study participants make sense suggests that the procedure is robust. Furthermore, the patterns shown have value because they mostly make sense; in the places where they deviate from what we expect, we are forced to ask whether the differences are the product of something that we have not considered in our method or whether the phenomena are genuinely unexplained. In both cases, these lead to interesting research questions that can be investigated in the future.

9.4 Continuation of the *PlaceInGIS* Project

With the conclusion of this dissertation, it is time to examine the future of the *PlaceInGIS* project. The basics of the PAS have been established and the results appear promising with many more areas to be explored. The question is what avenues of research should be pursued, how that development should proceed, and whether there are other projects that the *PlaceInGIS* project could follow with additional resources. The PAS was never intended to be the one and only software product developed by the *PlaceInGIS* project; there are many other ways that place can be explored using GIScience.

9.4.1 Ongoing Testing and Validation of the PAS

The analysis of the qualitative data stored in the PAS database can provide essential triangulation that may support the current approach, or may lead to modifications of the process. If we can show that the language used supports the place attachment values that have been derived quantitatively, we have another line of evidence to indicate that the process works, the data are correct, and they have been analyzed correctly.

In addition, the comments for each feature will be tied to the map of the study area, enabling us to click on a location on a summed surface in the PAS and "drill down" to the individual place attachment surfaces, feature surfaces, features and comments.

9.4.2 Future Papers Based on the PAS

For each feature discussed by study participants, they were invited to leave a comment about the feature. This has led to a small library of qualitative information. This information might be examined in future using qualitative analysis software. The results of this analysis will help to triangulate the quantitative results produced by the PAS, and in conjunction with the statistical validation process already employed, will further improve our confidence in the results produced by the PAS.

Now that each study participant has had a place attachment surface developed that represents their perception of the Colliery Dam Park study area, one thing that might be interesting to examine is whether the shapes form clusters. This would allow us to explore the connection between people and their place attachments further. The clusters would be based on some of the metrics already developed for Chapter 7 or new indices developed from morphometric analyses of the place attachment surfaces, such as volume, maximum height of the surface, mean value of the surface, or the area of the surface above the background value of 1.77.

If distinct clusters were discovered, it would be interesting to examine whether these correspond with known demographic and park use groups, or whether they identify some novel groupings of park users that had not been considered before. In essence, this is running the analysis from Chapter 7 "in reverse." Rather than determining whether demographic groups of people produce similar core and periphery areas, we can cluster place attachment surfaces morphometrically, and examine the characteristics of people who produce these place attachment surfaces. This may provide new insights into why people perceive the park in different ways.

A number of principal component analyses between the different demographic, meteorologic, and distance to road parameters showed some interesting components, which might be characterized as "peacefulness," "wilderness," and "exercise value." Some follow-up studies would be to:

- map and analyze the distance from surrounding road features against the place attachment values to assess the level of "peacefulness;"
- map and analyze the distance from the parking lots against the place attachment values to assess the "wilderness;" and
- map and analyze the difference in elevation and distance from the parking lots to assess the "exercise value" of different areas.

9.4.3 New Study Areas

Once the outstanding issues with the PAS have been addressed, there are further places where it might be employed again to study place attachment. These include:

- historical sites or historical districts of cities;
- disadvantaged neighborhoods or regions;
- larger parks (city, provincial, or national);
- areas of contested resource use;
- significant land development projects (e.g. subdivisions, malls, airports);
- contested national and regional boundaries (assuming that goodwill exists to resolve the disputes); and
- establishing geographical nomenclature (where does one neighborhood end and another begin?).

There are a number of interesting and valuable applications and locations where the PAS can be applied in future. One of the obvious applications is for First Nations land claim negotiations. In most of the Province of British Columbia, land was simply taken from First Nations groups without any treaties being signed.

The 2014 Tsilhqot'in decision in the Supreme Court of Canada made the issue of First Nations land claims critical for the future development of land in British Columbia. The case concerned the Province of British Columbia granting logging rights on the traditional territories of the Xeni Gwet'in and Tsilhqot'in First Nations. In response, the Province of British Columbia was taken to court by Chief Roger William of the Xeni Gwet'in First

Nation. The unanimous 8-0 decision affirmed the title of these First Nations to over 1700 square kilometers of land in central BC, most of their traditional territory. In making the decision, the Supreme Court set a precedent that unceded traditional lands of BC First Nations must be respected, giving these groups a great deal of control over any future land development on their traditional lands (McCue, 2014).

One of the issues is that the First Nations of British Columbia traditionally had overlapping territories with neighboring First Nations using the land for complementary, non-competing uses during different seasons (Rossiter & Wood, 2005). Of course, such a concept of land use is completely different from the European concept of exclusive title to the land, with artificial boundaries separating land parcels.

Because the PAS represents place attachment using fuzzy surfaces, it has a role to play in the treaty negotiation processes currently underway between the Federal, Provincial and First Nations governments. In part because of the complexity of these negotiations, a backlog of treaty negotiations will take decades to resolve at the current pace. The system can help to model the overlapping land uses and facilitate the conversion of such a land use model into the European model that now dominates.

Such an application would be interesting, not only because it has the potential to resolve competing land claims, but also because it can be used to gauge its effectiveness for reducing acrimony between groups. First Nations treaty negotiations represent a "safe" use of the PAS because the First Nations are generally united in viewing the Province of British Columbia and the Canadian Federal Government as their opponents, and because all groups are united under a single system of laws. As such, the PAS could be tested for the resolution of these disputes before the system is used to try to resolve more hotly contested land ownership questions.

Continuing this reasoning, a similar, but more difficult and controversial application might be used when different ethnic or religious groups have come into conflict over the control of particular areas or cities. In this case, competing groups may have radically different cultures, laws and overlapping artificial boundaries supported by military or paramilitary force. These types of land use conflicts at the sub-national or national level are much more difficult to solve than those that are found in British Columbia.

The PAS might prove valuable in two ways. First, it could be used to visualize the summed place attachment surfaces for different nations and cultural groups. This would help to differentiate those areas that are of greatest importance from those of lesser importance, and would help prioritize the locations at the center of the conflict for negotiation. Second, the Core & Periphery tool might be able to differentiate between the core areas, which would not be subject to negotiation, from the peripheral areas, which would be. If there were no overlap between core areas, this would act to de-escalate tensions immediately. Simply separating the areas into core and periphery using an automated, impartial system might play a key role in reducing any posturing or rhetoric, allowing for faster negotiations. Bringing vague and fluid concepts of ethnic values and nationality down to specific, visible places of contention would be a groundbreaking application.

A particularly cogent example would be to use the PAS to help redraw the boundaries in the Middle East to replace the artificial boundaries created as part of the World War I-era Sykes-

Picot Treaty, which created the nations of Syria and Iraq. Replacing these boundaries with more culturally appropriate ones could reduce much of the tension in the region.

The PAS offers a new way of recording, storing, analyzing and presenting information about place attachment. It has now been tested on a park environment, and needs to be tested in other environments where place attachment is an important factor. Expanding where such applications are used will help to identify limitations in the method and help to refine the design of the software, making it even easier to use.

9.4.4 Improving Data Collection

Recent advances in the capabilities of smart phones make it possible to use a smart phone as a data collection platform. The creation of a smartphone application that uses the phone's GPS receiver to record the location of places of importance, together with the date, time, level of importance and emotion has the potential to revolutionize data collection about place. Such an application could also collect qualitative information and automatically upload all the data to a central server.

Consolvo *et al.* (2007) point out that entering data on portable devices such as smartphones is faster if questions are in multiple choice, true-false, or Likert scale format, rather than being qualitative. Of course, the risk of this is that by making the questions more structured and easier to answer, we will introduce our biases into the survey results (Taylor & Overton, 1991). Rapidly maturing technologies for language recognition that can handle different dialects and ways of speaking might be one way to overcome the difficulties of entering qualitative data (IBM, 2016). Furthermore, such an approach would reduce spelling errors, making the information easier to understand. Once the data are entered, the opportunities for lexical analysis of the qualitative information are greatly increased.

There are many data that a smartphone could be used to collect. These fall into four classes, based on how the data are collected. The first class of data would be that which is entered deliberately by the study participant. When the user presses the "collect feature" button, some of the most important data could be collected automatically using the sensors on the smartphone. These would include the location of the feature being discussed, the time and date, and the amount of ambient noise. The awareness distance could be collected explicitly by having the participant walk away from the feature until it is no longer considered important, at which point they could press a button to finish data collection for that feature. Using the GPS receiver on the smartphone overcomes one of the limitations of the current study, which is the need to match verbal descriptions of features with pre-collected spatial data. It does this, however, at the cost of substituting lower accuracy spatial coordinates from a low-cost GPS chip on the smartphone for the high-quality spatial locations obtained by using professionally mapped features from a commercial-grade GPS unit.

A second class of data, such as the current weather conditions, the awareness distance and the participant's travel patterns shortly before and after pressing the "collect feature" button, could be obtained by processing within the application. Weather information could be collected automatically from the nearest weather station using internet connectivity, or even from a temporary weather station set up at the center of the place being studied. An alternate way to determine awareness distance would use ongoing motion tracking to monitor when the participants begin to slow down upon approaching the feature and when they resume a normal walking speed upon leaving the vicinity, in order to measure the awareness distance automatically. One tantalizing possibility is that we could measure the anisotropy of the awareness distance. Until now, because of a lack of data, we have had to assume that the awareness distance is uniform in all directions (i.e. circular). By analyzing all the points collected near the feature, we could determine the direction and speed of travel to generate a non-circular awareness distance. Presumably, such a distance would be greater along paths and in areas of easily traversed terrain, and lesser when travel was constrained due to heavy vegetation or a lack of paths on which to travel.

A third class of data would be entered by the participant manually after pressing the "collect feature" button. These data would be mandatory, and if not completed, the response would automatically be rejected; thus, by necessity, the number of questions would be kept to a minimum. These would include the place to which the feature belongs, the feature name, and questions related to place dependence and place identity. The first question – the place for which the data is being collected – might only be enabled when a study of multiple places is being performed. When data for only a single place is being collected, this datum would be fixed.

Finally, a fourth class of data would be optional. These would include photographs of the feature being collected, written or verbal comments, which would be converted to Standard English text for qualitative analysis, and the recording of a soundscape near the feature.

In conjunction with the smartphone app discussed above, parts of the PAS may also be employed to locate and rate the place attachment of different areas. Already, sites such as Wikimapia (http://wikimapia.org/ #lang=en &lat=49.148114&lon=-23.962517&z=15&m=b)

have been developed to display crowdsourced boundaries and information on top of Google Maps. If we developed a similar system to map individual features and rate them by place attachment over a course of years, a crowdsourced place attachment database could be constructed. The risk of this, as with any crowdsourced project, is that the information will contain a small number of significant inaccuracies, and may be prone to vandalism.

9.4.5 Longitudinal Studies

One interesting study that might be embarked upon using the PAS is a longitudinal survey to see whether the perceptions of place change for individual participants over time. It would be interesting to see whether individual perceptions change over the seasons or with age, but such a study would have to be carefully designed. The proposed removal of the Colliery Dams in 2012 was highly controversial and likely altered public perception of the park for a long period. Fortunately, the 2011-2012 data were collected during a relatively stable period, and we are confident that the effects seen in Chapter 7 are not the result of major events in the park. However, it does serve as a reminder that such a study would have to take place in a place that is deliberately chosen for its long-term stability.

We could also use a longitudinal survey to examine temporal changes to place, if we had repeated surveys of long-term participants conducted perhaps yearly over one or more decades. This area seems to be another in which the PAS may offer new insights. The first question to answer would be how to measure the rate of change of a place using the PAS, accounting for individual changes (e.g. aging, major life events) that affect place perception. Once we have this established, we could look at minimum, mean and maximum rates of change for a place. We might even be able to examine how to break down the factors that control change. For example, we might be able to determine how much change is institutionally driven and how much is individually driven, or we might be able to separate the strictly human changes from ecological changes to a place.

9.5 Moving the PAS out of the Lab

My first attempt to have study participants review and comment on the place attachment surfaces on the PlaceInGIS.com website was unsuccessful. I anticipated that study participants would have greater interest in viewing their results, and in winning the camera that was offered as an incentive to participate in the study. Unfortunately, I did not collect any contact information for the study participants, which would have been valuable for follow up studies.

Before the PAS is deployed again, having some method to contact willing participants for follow-up studies will need to be included in the research ethics application. In addition, we will need to reconsider our strategies for how we will interact with the public so that there is more of an ongoing dialog after we have surveyed each participant.

Furthermore, better methods of contacting and interacting with interested professionals will need to be devised. These needs could be resolved with a more formal outreach program for the project. Such a program would include for the public:

- modes of communication to be used;
- ways of explaining what data are being collected, why they are being collected, how they will be used, and how private data will be kept confidential;
- ways of describing what the PAS does for a general audience;
- methods for building trust and support for the project among members of the public; and
- a call for local experts to help us in the identification of important features in the study area and to review preliminary study results once they have been produced.

For the professional community, an outreach project would need to communicate:

- what the PAS does and how it works using appropriate professional jargon;
- how the PAS will benefit professional users; and
- how interested professional users ("early adopters") can become involved with the project, for example by reviewing initial project results.

These activities could be done during informal workshops or academic presentations, or by contacting key individuals directly. By mobilizing members of affected professional communities and the public prior to using the PAS for particular studies, we can increase the likelihood that the project will be received favorably.

We have already given a great deal of thought to the technical aspects of dealing with the public and professional communities. Although the place attachment surfaces for individuals and groups can help them to understand points of agreement and disagreement about their relationship with different places, most people are accustomed to dealing with solid, unambiguous lines on maps. The very concept of a three dimensional surface representing a place is bound to cause some confusion for both professionals and the public. This is why we explored methods for defuzzifying place boundaries to produce discrete boundaries compatible with traditional methods of using GIS. If areas of high place attachment are outlined in a form that is not overly complex, then these areas might be used by planners to identify zones where development should be restricted or prohibited. As such, the resulting polygons can be used as inputs for an overlay model to examine some of the constraints present on development. Such discrete boundaries can be generated for different genders, age classes, demographic groups and types of park users to identify commonalities in their perspectives and to help identify better ways to serve each of these groups.

9.6 Summary

The PAS has been difficult to develop, but the methodology and software appear to be relatively solid. The results produced make sense, although there are some minor issues. These may be methodological, or they may represent unknown findings about the study area. It will take several years to establish the validity of the technique in different situations. However, the development to date clearly shows two things: the concepts behind the approach work and they produce results that make sense. The approach shows great promise, has an auspicious future but requires some polishing to reach its full potential.

References

Adolphson, M., Kamens, E., & Matsumoto, S. (Eds.) (2007). Heian Japan centers and peripheries. Honolulu: University of Hawai'i Press.

Aitken, S., & Michel, S. (1995). Who contrives the 'real' in GIS?: Geographic information, planning and critical theory. *Cartography and Geographic Information Systems*, 22(1), 17-29.

Altman, I. & Low, S. (Eds.) (1992). *Place attachment*. New York: Plenum Press.

Appleton, K. & Lovett, A. (2005). GIS-based visualization of development proposals: reactions from planning and related professionals. *Computers, Environment and Urban Systems*, 29(4), 321-339.

Augé, M. (1992). Non-Places: Introduction to an anthropology of supermodernity. London: Verso.

Barrett, L. & Barrett D. (2001). An introduction to computerized experience sampling in psychology. Social Science Computer Review, 19(2), 175-185.

Batty, M, (1992). Geographic information systems: GIS in urban planning and policy analysis. In *GIS in regional development planning: Proceedings of the study group meeting on regional and global economic integration, development planning, and information technology, Nagoya, 11-14 November 1991* (United Nations Centre for Regional Development, Nagoya), 27-60.

Batty, M. (2013). Defining GeoDesign (= GIS + design ?). *Environment and Planning B: Planning and Design*, 40, 1-2.

Berry, B., Horton, F. & Abiodun, J. (1970). *Geographical perspectives on urban systems, with integrated readings*. Englewood Cliffs, N.J.: Prentice–Hall.

Berry, B & Wheeler, J. (Eds.) (2005). *Urban geography in America, 1950-2000: Paradigms and personalities.* New York: Routledge.

Bertrand, K., Bialik, M., Virdee, K., Gros, A. & Bar-Yan, Y. (2013). *Sentiment in New York City: A high resolution spatial and temporal view.* Cambridge, MA: New England Complex Systems Institute.

Bhalia, D. (2015). Detect non-linear and non-monotonic relationship between variables. *Listen Data.* Retrieved from http://www.listendata.com/2015/03/detect-non-linear-and-non-monotonic.html, Apr. 13, 2017.

Branting, S. (2014). Agents in Motion. In Steadman, S. & Ross, C. (Eds.) *Agency and identity in the ancient Near East: New paths forward*, pp. 47-59. New York: Routledge.

Britto, J., Habibi, P., Walters, S., Levin, M., & Nadel, S. (1996). Systemic complications associated with bacterial tracheitis. *Archives of Disease in Childhood, 74*: 249-250.

Brown, G. (2005). Mapping spatial attributes in survey research for natural resource management: Methods and applications. *Society and Natural Resources*, 18, 17-39.

Brown, G. (2006). Mapping landscape values and development preferences: A method for tourism and residential development planning. *International Journal of Tourism Research*, 8, 101-113.

Brown, G., and Raymond, C. (2007). The relationship between place attachment and landscape values: Toward mapping place attachment. *Applied Geography 27*(2), 89-111.

Brown, G., Raymond, C. & Corcoran, J. (2014). Mapping and measuring place attachment. *Applied Geography*, *57*, 42-53.

Brown, G. & Reed, P. (2012). Social landscape metrics: Measures for understanding place values from public participation geographic information systems. *Landscape Research*, *37*(1), 73-90.

Brown, G. & Weber, D. (2011). Public participation GIS: A new method for national park planning. *Landscape and Urban Planning*, *102*, 1-15.

Brunckhorst, D. & Reeve, I. (2006). A geography of place: Principles and application for defining 'eco-civic' resource governance regions. *Australian Geographer*, 37(2), 147-166.

Bugatti, S. & Everett, M (2005). Models of core/periphery structures. *Social Networks*, 21(4), 375-395.

Burrough, P. (1996). Natural objects with indeterminate boundaries. In P. Burrough, A. Frank (Eds.) *Geographic objects with indeterminate boundaries.* London: Taylor and Francis, 3-28.

Bush, C. (2011). Gorilla-masked man grabs woman. *Nanaimo News Bulletin, Dec. 27, 2011*. Retrieved from http://www.nanaimobulletin.com/news/136284358.html, Jan. 16, 2016.

Cacciapaglia, M., Yung, L., & Patterson, M. (2012). Place mapping and the role of spatial scale in understanding landowner views of fire and fuels management. *Society and natural resources*, **25**, 453-467.

Carver, S., Evans, A., Kingston, R., & Turton, I. (2001). Public participation, GIS, and cyberdemocracy: Evaluating on-line spatial decision support systems. *Environment and Planning B*, 28, 907-921.

Carver, S., Watson, A., Waters, T. Matt, R, Gunderson, K., & Davis, B. (2009). Developing computer-based participatory approaches to mapping landscape values for landscape and resource management. In Geertman S. & Stillwell J. (Eds.) *Planning support systems best practice and new methods*, 431-448. New York: Springer Science+Business Media.

Chiesura, A. (2004). The role of parks for the sustainable city. *Landscape and Urban Planning, 68,* 129-138.

Chrisman, N. (2006). *Charting the unknown: How computer mapping at Harvard became GIS*. Redlands, CA: ESRI Press.

Christaller, W. (1966). Central places in Southern Germany, The pioneer work in theoretical economic geography. Englewood Cliffs, NJ: Prentice-Hall.

City Explained, Inc. (2017). CommunityViz: Software for Planners (Version 5.1.2) (Software). Available from http://communityviz.city-explained.com/, Mar. 16, 2017.

City of Nanaimo (n.d.). *Chase River Watershed*. http://www.nanaimo.ca/assets/Departments/Community~Planning/Environmental~Planning/Watersheds/ChaseRiver.pdf, Apr. 13, 2017.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd Ed.)*. New York, NY: Psychology Press.

Consolvo, S., Harrison, B., Smith, I., Chen, M., Everitt, K. Froehlich, J. & Landay, J. (2007). Conducting in situ evaluations for and with ubiquitous computing technologies. *International Journal of Human-Computer Interaction*, 22(1-2), p. 103-118.

Couclelis, H. (1991). Requirements for planning-relevant GIS: A spatial perspective. *Papers in regional scienc*e, 70(1), 9-19.

Couclelis, H. (1996). Towards an operational typology of geographic entities with ill-defined boundaries. In P. Burrough & A. Frank (Eds.) *Geographic objects with indeterminate boundaries.* London: Taylor and Francis, 45-55.

Cresswell, T. (2004). Place: A short introduction. Malden, MA: Blackwell.

Dennis, S. (2006). Prospects for qualitative GIS at the intersection of youth development and participatory urban planning. *Environment and planning A*, 38, 2039-2054.

Devine-Wright, P. (2009). Rethinking NIMBYism: The role of place attachment and place identity in explaining place-protective action. *Journal of community & applied social psychology,* 19, 426-441.

Diao, M. (2015). Are inner-city neighborhoods Underserved? An empirical analysis of food markets is a U.S. metropolitan area. *Journal of Planning Education and Research, 35*(1), 19-34.

Dornič, S. (1967). Subjective distance and emotional involvement: a verification of the exponent invariance. *Reports from the psychological laboratories*, *237*. Stockholm: University of Stockholm.

Eisenhauer, B., Krannich, R. & Blahna, D. (2000). Attachments to special places on public lands: An analysis of activities, reason for attachments, and community connections. *Society and Natural Resources* 13, 421–441.

Ekman, G. & Bratfisch, O. (1965). Subjective distance and emotional involvement: A psychological mechanism. *Acta Psychologica*, 24, 430-437.

Elwood, S. (2006). Critical issues in participatory GIS: Deconstructions, reconstructions, and new research directions. *Transactions in GIS*, 10(5), 693-708.

ESRI [Environmental Systems Research Institute] (2017a). *ArcGIS 10.3.1* (Computer Software) Redlands, CA: Environmental Systems Research Institute, Inc.

ESRI (2017b). *Summarizing data in a table*. Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#//005s00000055000000, Apr. 13, 2017.

ESRI (2017c). *Merge (data management)*. Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#//001700000055000000, Mar. 30, 2017.

ESRI (2017d). *Extract values to points (Spatial analyst)*. Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#//009z0000002t000000, Mar. 30, 2017.

ESRI (2017e). *Surface volume (3D analyst)*. Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#//00q900000027000000, Mar. 30, 2017.

ESRI (2017f). *Slice (Spatial Analyst).* Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#//009z000000ss000000, Mar. 30, 2017.

ESRI (2017g). *Region Group (Spatial Analyst).* Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#//009z00000039000000, Mar. 30, 2017.

ESRI (2017h). *Polyline to Raster (Conversion).* Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#//001200000031000000, Mar. 30, 2017.

ESRI (2017i). *Reclassify (3D Analyst).* Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#/Reclassify/00q90000007n000000/, Mar. 30, 2017.

ESRI (2017j). *Extract by Mask (Spatial Analyst).* Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#//009z0000002n000000, Mar. 30, 2017.

ESRI (2017k). *Aggregate Polygons (Cartography).* Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#//00700000000s000000, Mar. 30, 2017.

ESRI (2017l). *Smooth Polygon (Cartography).* Retrieved from http://resources.arcgis.com/en/help/main/10.2/index.html#//007000000013000000, Mar. 30, 2017.

Faga, B. (2006). Designing public consensus: The civic theater of community participation for architects, landscape architects, and urban designers. Hoboken, NJ: Wiley.

Fisher, P, 1996, Boolean and Fuzzy Regions. In Burrough, P. & Frank, A. (Eds.) *Geographic objects with indeterminate boundaries* London: Taylor and Francis.

Fitzjohn, M. (2007). Viewing places: GIS applications for examining perception of space in the mountains of Sicily. *World Archaeology*, 39(1), 36-50.

Frank, A. (1967). *Capitalism and underdevelopment in Latin America*. New York: Monthly Review Press.

Frank, A. (1996). The prevalence of objects with sharp boundaries in GIS. In Burrough P. & Frank, A. (Eds.) *Geographic objects with indeterminate boundaries* (pp. 29-40). London: Taylor and Francis.

Geltman, K. (2014). *The Simulated Annealing Algorithm.* Retrieved from http://katrinaeg.com/simulated-annealing.html, Jan. 16, 2016.

Golledge, R. (1978). Representing, interpreting and using cognized environments. *Papers of the regional science association, 41*.

Goodchild, M. (1992). Geographical information science. *International journal of geographical information systems*, 6(1), 31-45.

Gorman, T. (2012). City plans to remove two century-old dams. *Nanaimo news bulletin*, 24(80), Nov. 1, 2012, p. 1.

Gould, P. & White, R. (1992). *Mental maps, 2nd Ed.* New York, Routledge.

Gunderson, K. & Watson, A. (2007). Understanding place meanings in the Bitterroot National Forest, Montana. *Society and Natural Resources, 20,* p. 705-721.

Hanna, K. & Culpepper, R. (1998). GIS in site design: New tools for design professionals. New York: Wiley.

Harewood Centennial Committee (1967). *Harewood: land of Wakesiah.* Nanaimo, BC: Harewood Centennial Committee.

Harris, T., Weiner, D., Warner, T., & Levin, R. (1995). Pursuing social goals through participatory geographic information systems. In J. Pickles (Ed.) *Ground truth: The social implications of geographic information systems.* New York: Guildford Press, 196-222.

Harvey, D. (1996). *Justice, nature & the geography of difference*. Oxford: Blackwell.

Hayden, D. (1995). *The power of place: Urban landscapes as public history*. Cambridge, MA: MIT Press.

Hill, K., & Binford, M. (2002). The role of category definition in habitat models: Practical and logical limitations of using Boolean, indexed, probabilistic, and fuzzy categories. In J. Scott, P. Heglund, M. Morrison, J. Haufler, M. Raphael, W. Wall & F. Samson (Eds.) *Predicting species occurrences: Issues of accuracy and scale.* Washington D.C.: Island Press, 97-106.

Hooge, P. & Eichenlaub, B. (2000). *Animal movement extension to ArcView, version 20*. Anchorage, AK: Alaska Biological Science Center, US Geological Survey. Retrieved from http://alaska.usgs.gov/science/biology/spatial/gistools/index.php/, Dec. 6, 2016.

Hopkins, T. (1996). The age of transition: Trajectory of the world-system, 1945-2025. London: Zed Books.

Hudson's Bay Company (2016). *Our History: Places: Forts & Posts: The Nanaimo Bastion.* Retrieved from www.hbcheritage.ca/hbcheritage/history/places/forts/nanaimo, Feb. 4, 2017.

IBM (2015). IBM SPSS Statistics (Version 23.0) [software]. Armonk, NY: IBM Corp.

IBM (2016). *What is Watson?* Retrieved from http://www.ibm.com/watson/what-is-watson.html, July 20, 2016.

Jackson, J. (1994). *A sense of place, a sense of time*. New Haven, CT: Yale University Press.

Jacquez, G., Maruca, S. & Fortin, M.-J. (2000). From fields to objects: A review of geographic boundary analysis. *Journal of Geographical Systems*, 2, 221-241.

Johnson, P., Parker, J. & Sedola, G. (1966). *Nanaimo: Scenes from the past*. Nanaimo BC: Nanaimo & District Museum Society.

Jorgensen, B. & Stedman, R. (2011). Measuring the spatial component of sense of place: a method for research on the spatial dynamics of places. *Environment and Planning B, Planning and Design*, *38*, 795-813.

Kaltenborn, B. (1997). Nature of place attachment: A study among recreation homeowners in Southern Norway. *Leisure Sciences*, 19(3), 175-189.

Kaltenborn, B. & Bjerke, T. (2002). Associations between landscape preferences and place attachment: A study in Røros, Southern Norway. *Landscape Research,* 27(4), 381-396.

Kendall, G. (2015). *Simulated Annealing (Artificial Intelligence Methods Course Handout, G5BAIM).* Nottingham: University of Nottingham. Retrieved from http://www.cs.nott.ac.uk/~pszgxk/aim/, Jan. 16, 2016.

Kirkpatrick, S., Gelatt, Jr., C., & Vecchi, M. (1983). Optimization by simulated annealing. *Science, 220*(4598), 671-680.

Kitchen, R. (2014). *The data revolution: Big data, open data, data infrastructures & their consequences.* London: SAGE Publications Ltd.

Kitchin, R. & Blades, M. (2002). *The cognition of geographic space*. London: IB Tauris.

Klir, G. & Yuan, B. (1995). *Fuzzy sets and fuzzy logic—Theory and applications*. Englewood Cliffs, NJ: Prentice-Hall.

Klosterman, R. (2017). What if? (Version 2.0). (Software). Available from http://www.whatifinc.biz/, Mar. 16, 2017.

Kneafsey, M. (1998). Tourism and place identity: A case-study of rural Ireland. *Irish Geography*, 21(2), 111-123.

Kuhn, T. (1970). The Structure of Scientific Revolutions, 2nd Edition. In Neurath, O. (Ed.) *International encyclopedia of unified science, Vol. 2 No. 2.* Chicago: University of Chicago Press.

Laerd Statistics (2015). *Statistical tutorials and software guides*. Retrieved from https://statistics.laerd.com/, Jun. 23, 2016.

Leung, Y. (1987). On the Imprecision of Boundaries. *Geographical analysis*, 19(2), 125-151.

Levy, I., Hasson, U., Avidan, G., Hendler, T. & Malach, R. (2001). Center-periphery organization of human object areas. *Nature Neuroscience*, *4*(5), 533-539.

Lewicka, M. (2010). Place attachment: How far have we come in the last 40 years? *Journal of Environmental Psychology*, 31, 207-230.

Leynard, A. (1982). *The Coal Mines of Nanaimo*. Nanaimo, BC: Nanaimo Historical Society.

Lowery, D. & Morse, W. (2012). A qualitative method for collecting spatial data on important places for recreation, livelihoods, and ecological meanings: Integrating focus groups with public participation geographic information systems. *Society and Natural Resources*, *26*, 1422-1437.

Lynch, K. (1960). *The image of the city*. Cambridge, MA: MIT Press.

McCall, M. (2003). Seeking good governance in participatory-GIS: A review of processes and governance dimensions in applying GIS to participatory spatial planning. *Habitat international*, 27, 549-573.

McCue, D. (2014, Dec. 23). Tsilhqot'in land ruling was a game changer for B.C. *CBC News*. Retrieved from http://www.cbc.ca/news/indigenous/tsilhqot-in-land-ruling-was-a-game-changer-for-b-c-1.2875262, Apr. 2, 2017.

McGrew, Jr., J. & Monroe, C. (2000). An Introduction to Statistical Problem Solving in Geography, 2nd Ed. Boston: McGraw-Hill.

McHaffie, P. (1995). Manufacturing Metaphors: Public Cartography, the Market, and Democracy. In Pickles, J. (Ed.) *Ground Truth: The Social Implications of Geographic Information Systems*. New York: Guildford Press, 113-129.

Malpas, J. (1998). Finding place: Spatiality, locality, and subjectivity, in Light, A. & Smith, J., Eds. *Philosophies of place, Philosophy and geography III*. Lanham, MD: Rowman & Littlefield Publishers.

Manzo, L. (2005). For better or worse: Exploring multiple dimensions of place meaning. *Journal of Environmental Psychology, 25*, 67-86.

Marshall, K. (1996). Formal and narrative models and their value as instruments of understanding. In *Concepts in human geography* Eds. Earle, C., Mathewson, K. & Kenzer, K. (pp. 293-321). London: Rowman & Littlefield Publishers, Inc.

Massey, D. (1997). A global sense of place in Barnes, T. and Gregory D., Eds. *Reading human geography: the poetics and politics of inquiry*, p. 315-323. London: Edwin Arnold.

Montello, D., Goodchild, M., Gottsegen, J. & Fohl, P. (2003). Where's downtown?: Behavioural methods for determining referents of vague spatial queries." *Spatial cognition and computation*, *3*(2 & 3), 185-204.

Nanaimo and District Historical Society (1983). *Nanaimo: The story of a city*. Nanaimo, BC: Nanaimo and District Historical Society.

Nobel Media AB (2014). The 2014 Nobel Prize in Physiology or Medicine - Advanced Information. Retrieved from http://www.nobelprize.org/nobel_prizes/medicine/laureates/2014/advanced.html, June 27, 2017.

Norcross, E. (Ed.) (1979). *Nanaimo retrospective: The first century.* Nanaimo, BC: Nanaimo Historical Society.

Norton, B. & Hannon, B. (1998). Democracy and sense of place values in environmental policy, in Light, A & Smith, J., (Eds.) *Philosophies of Place, Philosophy and Geography III*. Lanham, MD: Rowman & Littlefield Publishers.

O'Sullivan, D. & Unwin, D. (2010). *Geographic Information Analysis.* Hoboken, N.J.: Wiley.

Parks Canada (2015a). *Gulf Islands National Park Reserve of Canada.* Retrieved from http://www.pc.gc.ca/eng/pn-np/bc/gulf/index.aspx, May 16, 2015.

Parks Canada (2015b). *Gulf Island National Park Reserve.* Retrieved from http://www.pc.gc.ca/eng/pn-np/bc/gulf/carte-map-nfl.aspx#a25, May 16, 2015.

Parks Canada (2015c). *Gulf Islands National Park Reserve of Canada: Facilities and Services.* Retrieved from http://www.pc.gc.ca/eng/pn-np/bc/gulf/visit/visit2.aspx, May 16, 2015.

Plutchik, R. (1962). *The emotions: Facts, theories, and a new model.* New York: Random House.

Plutchik, R. (1980). *Emotion: A psychoevolutionary synthesis*. New York: Harper and Row.

Porter, P. & Sheppard, E. (1998). *A World of Difference: Society, Nature, Development*. New York: Guildford Press.

Pred, A. (1984). Place as historically contingent process: Structuration and the time-geography of becoming places. *Annals of the AAG*, 74(2), 279-297.

Reades, J., Calabrese, F., & Ratti, C. (2009). Eigenplaces: analysing cities using the time-space structure of the mobile phone network. *Environment and Planning B*, 36, 824-836.

Relph, E. (1976). Place and placelessness. London: Pion.

Rombach, M., Porter, M., Fowler, J., & Mucha, P. (2014). Core-periphery structure in networks. *SIAM journal of applied mathematics 74*(1), 169-190.

Rossiter, D. & Wood, P. (2005). Fantastic topographies: neo-liberal responses to Aboriginal land claims in British Columbia. *Canadian Geographer*, 49(4), 352-366.

Russell, J. (2003). Core affect and the psychological construction of emotion. *Psychological Review*, 110(1), 145-172.

Saarinen, T. (1969). *Perception of the Environment*. Washington, DC: Association of American Geographers.

Sack, R. (1997). *Homo Geographicus: A framework for action, awareness, and moral concern.* Baltimore: Johns Hopkins University Press.

Sagan, C. (1990) A pale, blue dot. *Parade Magazine*, Sept. 9, 1990. Retrieved from https://news.google.com/newspapers?id=_upSAAAAIBAJ&sjid=noEDAAAAIBAJ&pg=4800,1930437&dq=pale-blue-dot+-book&hl=en, Jan. 12, 2017.

Sanders, J. and Orrison, W. Jr. (1995). Functional Magnetic Resonance Imaging. In Orrison, W. Jr., Lewine, J., Sanders, J. & Hartshorne, M. (Eds.), *Functional Brain Imaging*. St. Louis: Mosby-Year Book, Inc.

Sanoff, H (2000). Community participation methods in design and planning. New York: Wiley.

Schneider, M. (1996). Modelling spatial objects with undetermined boundaries using the Realm/ROSE approach in P. Burrough & A. Frank (Eds.) *Geographic objects with indeterminate boundaries.* London: Taylor and Francis, 141-152.

School-Based Weather Station Network, (2016). Vancouver Island University. Retrieved from http://www.islandweather.ca/station.php?id=123, Jan. 7, 2016.

Sester, M., Bernard, L. & Paelke, V. (Eds.). (2009). *Advances in GIScience: Proceedings of the 12th AGILE Conference.* Dordrecht: Springer.

Sheppard, E (1995). GIS and society: Towards a research agenda. *Cartography and Geographic Information Systems*, 22(1), 5-16.

Sheppard, E. (2001). Quantitative geography: representations, practices, and possibilities. *Environment and Planning D 19*, 535-554.

Smith, B. (1995). On drawing lines on a map. *International conference COSIT '95*, Semmering, Austria: Springer.

Smith, J., Light, A. & Roberts, D. (1998). Introduction: Philosophies and Geographies of Place, in Light, A & Smith, J., Eds. *Philosophies of Place*, Philosophy and Geography III. Lanham, MD: Rowman & Littlefield Publishers.

Soja, E. (1989). *Postmodern geographies: The reassertion of space in critical social theory*. London: Verso.

Spindler, B. (2016). *The transglobe expedition*. Retrieved from http://www.southpolestation.com/trivia/history/transglobe.html, Dec. 12, 2016.

Stedman, R. (2002). Toward a social psychology of place: Predicting behaviour from place-based cognitions, attitude, and identity. Environment and Behavior, 34(5), 561-581.

Stedman, R. (2003). Is it really just a social construction?: The contribution of the environment to a sense of place. *Society and Natural Resources*, 16, 671-685.

Strzalecki, A. (1978). The relation between subjective distance and emotional involvement: further experiments. *Acta Psychologica*, 42, 429-440.

Taylor, P (1990) GKS. *Political Geography Quarterly*, 9(3), 211-212.

Taylor, P. and M. Overton (1991). Further thoughts on geography and GIS: A preemptive strike? *Environment and Planning A*, 23, 1087-1094.

Thrift, N. (1994). Inhuman Geographies: Landscapes of Speed, Light and Power. In Cloke, P., Doel, M., Matless, D. Phillips, M. & Thrift, N. (Eds.) *Writing in the rural: Five cultural geographies*. London: Paul Chapman.

Transglobe Expedition (1981). *Around the world the long, hard way.* (Los Angeles trade show brochure). Retrieved from http://www.southpolestation.com/trivia/history/brochure.pdf, Dec. 12, 2016.

Tuan, Yi-Fu (1977). Space and place: The perspective of experience. Minneapolis: University of Minnesota Press.

Von Thünen, J. & Hall, P. (1966). *The Isolated State.* Oxford: Pergamon Press.

Vorkinn, M. & Riese, H. (2001). Environmental concern in a local context: The significance of place attachment. *Environment and behavior*, 33(2), 249-263.

Webster, C (1993). GIS and the scientific inputs to urban planning: Part 1: description. *Environment and Planning B*, 20(6), 709-728.

Willander, J. & Larsson, M. (2006). Smell your way back to childhood: Autobiographical odor memory. Psychonomic Bulletin & Review, 13(2), 240-244.

Williams, D. (2014). Making sense of 'place': Reflections on pluralism and positionality in place research. *Landscape and Urban Planning*, 131, 74-82.

Williams, D., Patterson, M., Roggenbuck, J. & Watson, E. (1992). Beyond the commodity metaphor: Examining emotional and symbolic attachment to place. *Leisure Sciences, 14, 29-46.*

Williams, D., Stewart, W. & Kruger, L. (2013). The emergence of place-based conservation. In Stewart, W., Williams, D. & Kruger, L. (Eds.) *Place-based conservation: Perspectives from the social sciences*. Dordrecht: Springer.

Williams, D. & Vaske, J. (2003). The measurement of place attachment: Validity and generalizability of a psychometric approach. *Forest Science*, 49(6), 830-840.

Williamson & Lawton (1991). Fractal geometry of ecological habitats. In Bell, S., McCoy, E., & Mushinsky, H. (Eds.) *Habitat Structure: The physical arrangement of objects in space*, pp 69-86. Dordrecht: Springer Science+Business Media.

Xu, H. (1995). The roles of GIS in planning: a critical appraisal of the technology for urban and regional planning. (Unpublished Master's Thesis). University of British Columbia, Vancouver, B.C.

Zadeh, L. (1965). Fuzzy Sets. *Information and Control, 8*, 338-353.

Zent, C. (2016). *ArcGIS Desktop and VBA Moving Forward.* Retrived from https://blogs.esri.com/esri/arcgis/2016/11/14/arcgis-desktop-and-vba-moving-forward/?mkt_tok=eyJpIjoiWkdFM04yVTBOalJrWkRFeiIsInQiOiJHWk9CYTc2NDFOOFlOb0x3RkhsV0sxcFwvb2I0Q1BkXC9wdzZnTTU2ODNLQWpxOTFybjl1bEhUVmhsUzNFc2dTRFJDRGQ1ZDRvK2w5eG40bHBKVm5QSmdFZW9YZ2pKZE5cLzk1QXJwYUIrOEhcL1Q1NW15NUxYZHhQTDZ5TVd6OXVqSXkifQ%3D%3D, Dec. 14, 2016.

Zukin, S. (1993). Market, place and landscape in *Landscapes of power: From Detroit to Disney World* (pp. 3-25). Berkeley: University of California Press.

Appendix A: Primary and Secondary Emotions Used in the PAS

Primary Emotions

Emotion	Affect	Synonym
Acceptance	4.00	
Admiration	7.00	
Admission	4.16	
Amazement	8.30	
Anger	8.40	
Annoyance	5.00	
Anticipation	7.30	
Apprehension	6.40	
Astonishment	9.30	
Attentiveness	5.86	
Boldness	3.00	
Boredom	4.70	
Calmness	3.30	
Closeness	4.00	Acceptance
Confusion	9.30	Astonishment
Dejection	6.26	
Detachment	3.00	
Disgust	7.60	
Dislike	5.50	
Distance	3.00	
Distraction	5.00	
Ecstasy	10.00	
Excitement	9.00	
Expectancy	6.76	
Fear	7.96	
Gloominess	5.50	
Grief	8.83	
Happiness	7.10	

Emotion	Affect	Synonym
Incompleteness	6.26	Dejection
Incorporation	3.56	
Interest	4.50	
Joy	8.10	
Loathing	9.10	
Loss	8.83	Grief
Pain	8.83	Grief
Panic	9.75	
Pensiveness	4.40	
Pleasure	5.70	
Rage	9.90	
Rashness	3.00	Boldness
Relaxation	3.00	
Sadness	6.80	
Serenity	4.36	
Set	3.56	
Shamelessness	3.00	
Sorrow	7.53	
Surprise	7.26	
Terror	10.13	
Timidity	4.03	
Tiresomeness	4.50	
Togetherness	4.00	Acceptance
Trust	3.00	
Vigilance	9.00	
Weariness	4.70	Boredom
Wonder	8.30	Amazement

Bolded emotions were provided to participants on the reference card.

Secondary Emotions

Emotion	Affect	Combination / Synonym
Aggression	7.58	Expectancy + Anger
Alarm	7.61	Surprise + Fear
Amusement	7.68	Delight
Anxiety	7.36	Fear + Expectancy
Awe	7.61	Alarm
Callousness	4.85	Boredom + Annoyance
Caution	7.36	Anxiety
Completion	6.13	Intimacy
Conceit	7.43	Optimism
Contempt	8.00	Disgust + Anger
Courage	7.43	Optimism
Cowardliness	7.36	Anxiety
Cruelty	7.88	Rage + Attentiveness
Curiosity	5.63	Acceptance + Surprise
Cynicism	7.18	Disgust + Expectancy
Delight	7.68	Joy + Surprise
Despair	7.75	Fear + Sorrow
Disappointment	7.40	Embarrassment
Disapproval	4.70	Pensiveness + Distraction
Discovery	7.18	Surprise + Happiness
Distrust	7.36	Anxiety
Dominance	6.20	Anger + Acceptance
Dread	7.36	Anxiety
Embarrassment	7.40	Surprise + Sorrow
Envy	7.97	Sorrow + Anger
Fatalism	5.38	Expectancy + Acceptance
Forlornness	7.57	Misery
Friendship	6.05	Love
Guilt	7.75	Despair
Hate	8.00	Disgust + Anger
Hopefulness	7.43	Optimism
Hostility	8.00	Hate

Emotion	Affect	Combination / Synonym
Indignation	8.00	Hate
Innocence	5.30	Shamelessness + Joy
Intimacy	6.13	Joy + Admission
Jealousy	7.97	Envy
Kindness	3.96	Incorporation + Serenity
Love	6.05	Joy + Acceptance
Misery	7.57	Sorrow + Disgust
Modesty	5.98	Submission
Morbidness	7.85	Disgust + Joy
Nervousness	6.13	Attentiveness + Apprehension
Nostalgia	5.77	Resignation
Optimism	7.43	Expectancy + Joy
Outrage	7.83	Anger + Surprise
Patience	3.65	Calmness + Acceptance
Pessimism	7.15	Sorrow + Expectancy
Pity	7.78	Shame
Pride	8.25	Anger + Joy
Prudishness	7.78	Shame
Remorse	7.57	Misery
Repentance	6.13	Admission + Joy
Resentment	8.00	Hate
Resignation	5.77	Acceptance + Sorrow
Revenge	7.58	Aggression
Satisfaction	7.68	Delight
Scorn	8.00	Hate
Sentimentality	5.77	Resignation
Shame	7.78	Fear + Disgust
Stubbornness	7.58	Aggression
Submission	5.98	Acceptance + Fear
Sullenness	7.97	Envy
Unkindness	5.25	Dislike + Annoyance

Bolded emotions were provided to participants on the reference card.

Appendix B: Fuzzy Logic and Fuzzy Sets

Fuzzy logic is a superset of Boolean logic, which permits not only assertions of "true" and "false," but also the handling of degrees of membership, which allows uncertainty to be examined within a logical framework. Using fuzzy logic, we can assert not only that a statement is true or false, but also that we have an 80% belief that a statement is true.

Fuzzy sets are collections of objects with degrees of membership that range from 0.0 to 1.0 (Zadeh, 1965), or which can be scaled to such a range. The objects may be anything from people to trees to pixels in a continuous raster. We may ask, "Is a person religious," or "is a tree tall?" Although these questions can be answered as True or False using Boolean logic, it is frequently more revealing to answer the question using fuzzy logic. For instance, we might find out that a person who considers herself religious (true) is only 90% religious when compared with all people questioned, or that a coast redwood (*Sequoia sempervirens*) tree in California is not only tall (true), but that it is 100.0000% tall, i.e. it is the tallest single tree in the world.

With fuzzy sets, we are using a continuous raster to represent a ***degree of membership***, which is an inherently nonstatistical concept (Zadeh, 1965). It is important to recognize that continuous rasters are commonly used in GIS to represent probability density functions, i.e. the probability that a random variable meets certain criteria. It is important not to confuse fuzzy logic and probability, because what they represent and how they are processed are dissimilar (Fisher, 1996; Zadeh, 1965).

Logical and Mathematical operators have been developed to handle the combination of Fuzzy Sets (Zadeh, 1965). The same principles for two-dimensional features apply for three-dimensional fuzzy surfaces; the operations are simply applied for all pixels in the surface.

The union of fuzzy sets A and B (Fuzzy OR) is the smallest fuzzy set containing both A and B. This is formally implemented as:

$$f_C(x) = \mathrm{Max}[\, f_A(x),\ f_B(x)], \quad \forall\ x \in X$$ **Equation B.1**

Where:
$f_A(x)$, $f_B(x)$, $f_C(x)$ are fuzzy sets A, B and C.

In other words, the membership function of fuzzy set C is the maximum of the membership functions of fuzzy sets A and B for all values of x that are an element of X, the universe of discourse. More compactly, this equation can be written as:

$$f_C = f_A \vee f_B$$ **Equation B.2**

Where the $\vee$ operator represents the maximum, and it is assumed that the function acts on all values of *x*. Similarly, the intersection of fuzzy sets A and B (fuzzy AND) can be represented using the compact form as:

$$f_C = f_A \wedge f_B$$ **Equation B.3**

Where the $\wedge$ symbol represents the minimum of the values at the same position. These can be represented graphically by showing the fuzzy union and fuzzy maximum of two fuzzy sets, f_A and f_B (Figure B1).

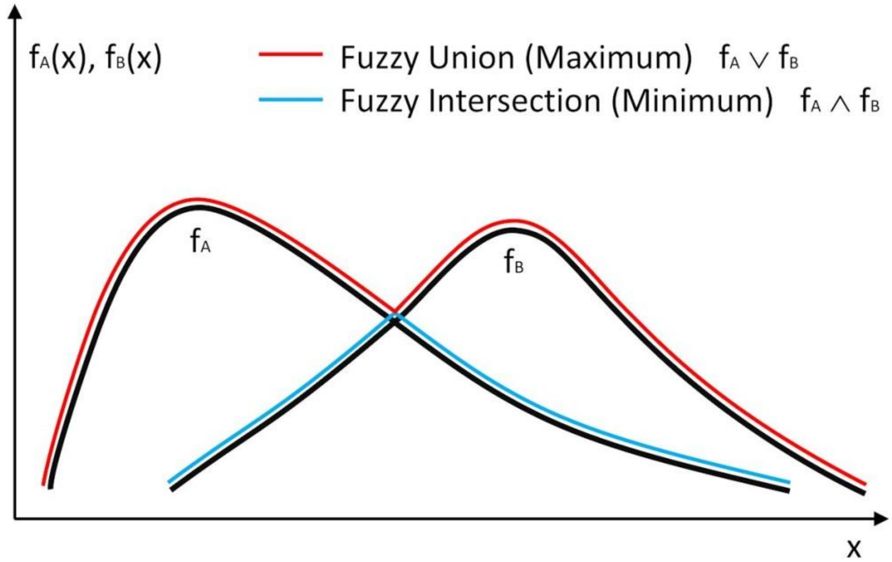


Figure B.1. The fuzzy union and intersection of two fuzzy sets, f_A and f_B. Colored lines have been offset from the fuzzy set curves for clarity (after Zadeh, 1965).

Appendix C: Main Tables of the Place Analysis System

Mainform_ Participant	*OBJECTID* *OBJECTID*	Participant Long Int	Years_Visiting Short Int	How_Often String 1	Age Short Int	Gender String 1	Postal_Code String 6	Ethnicity_ID Short Int	Purpose Short Int	Occupation String 64	Education Short Int	Purpose_ Other String 64
		Minimum = 0 Maximum = 999999999	0 = Less Than 1 1 = 1 2 = 2 3 = 3 4 = 4 5 = 5-7 8 = 8-10 11 = More than 10	D = Daily S = Several Times per Week W = Weekly 2 = Every 2 Weeks M = Monthly I = Infrequently	Minimum = 0 Maximum = 110	M = Male F = Female		1=None 2=Canadian 3=English 4=French 5=Scottish 6=Irish 7=German 8=Italian 9=First Nations 10=Ukrainian 11=Chinese 12=Dutch 13=Polish 14=South Asian 15=Jewish 16=Norwegian 17=Welsh 18=Portuguese 19=Swedish 20=Russian 21=Hungarian 22=Filipino 23=American 24=Spanish 25=Greek 26=Jamaican	0=Unknown 1=Walking 2=Running 3=Walking Dog 4=Swimming 5=Sunbathing 6=Commuting 7=Cycling 8=Fishing 9=Other		0=Unknown 1=Elementary 2=Secondary 3=University/College 4=University Postgraduate	

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Mainform_ Questionnaire	*OBJECTID* *OBJECTID*	Participant Long Int	Collection_Date Date	Collection_X Float	Collection_Y Float	Temp Short Int	Pct_Cloud Short Int	Rain Short_Int	Wind Short_Int	Sun Short_int	Selection_Type Short_Int	Entrance_ID Short Int	Reject Short Int	Reject_Reason String 254
		Minimum = 0 Maximum = 999999999	Minimum = 2011.06.01 Maximum = 2012.12.31	Minimum = 160000 Maximum = 834000	Minimum = 0 Maximum = 10000000	Minimum = -90 Maximum = 60	Minimum = 0 Maximum = 100	0 = False 1 = True	0 = False 1 = True	0 = False 1 = True	1 = Random 2 = Voluntary 3 = Convenience	Minimum = 1 Maximum = 8	0 = False 1 = True	

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Mainform_ Features	*OBJECTID* *OBJECTID*	Participant Long Int	Decay_Fn String 16	Exponent Float	Given _Name String 127	Benefit _Type String 1	Importance Long Int	Benefit_ Dist Float	Emotion String 16	Emotional _Int Float	Imp_Because String 2147483647	Feat_ Importance Float	Mean_ Centre_X Double	Mean_ Centre_Y Double
		Minimum = 0 Maximum = 999999999	L = Linear G = Gaussian E = Exponential O = Logistic H = Hyperbolic Tangent R = Logarithmic2 A = Logarithmic3 F = Fisher, 1994 viewshed decay			D = Distance V = Visual	1 = Very Unimportant 2 = Unimportant 3 = Somewhat Unimportant 4 = Neutral 5 = Somewhat Important 6 = Important 7 = Very Important							

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Mainform_ MultiObject	*OBJECTID* *OBJECTID*	*Feature_OBJECTID* Long Int	*Feature_ID* Long Int

Object_ LUT	*OBJECTID* *OBJECTID*	Official_Name String 255	Layer String 64	Official_Description String 2147483647	Layer_Type String 1	*Feature_ID* Long Int
					A = Area L = Line P = Polygon	