Stream network of Hanyang, a city of water

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ABSTRACT
This study was conducted to investigate the stream network formed in Hanyang and the topographic features of the surrounding areas for the purpose of identifying the impact of Hanyang’s stream network on its city formation. To this end, three substudies were conducted: (i) Topographic restoration of late Joseon using a digitized map including the stream network of the Joseon period and a cadastral map; (ii) Identification and explanations of the discrepancies between the digitally restored stream network and the real stream network by superposing the former upon the latter; (iii) Identification of the Hanyang’s stream network on its urban structure. The results of this study can be summarized as follows: First, the waterways derived by GIS analysis and those on the 1912 Cadastral Map were verified to general coincide with each other, but some changed waterways were observed. Second, the watershed and administrative boundaries general coincided.

1. Introduction
Hanyang, the capital city of Joseon (the last dynasty of Korea, 1392–1897), known today as Seoul, was located in the basin surrounded with the so-called inner four mountains (Naesasan), namely Baegak, Naksan, Mongmyeok, and Inwang. Many streams flowing down from Naesasan come together in the Middle Stream (today’s Cheonggyecheon Stream), which flows through Igansumun (two-arch water gate) and Ogansumun (five-arch water gate) into the Jungnangcheon Stream. After passing through Salgoji Bridge, Jungnangcheon Stream enters the Han river. The west-east orientation of stream flow changes back westwards after joining the Han River. Tributaries flowing down from Eungbong, the eastern peak of Baegak, one of the four inner mountains, should be studied within the dynamic structural framework of the streams as natural elements and the city as an anthropogenic element.

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The tributary-related changes of historical space should hence be studied from a complexly intertwined perspective encompassing the geographic viewpoint of exploring the nature impacting the spatial formation and evolution, viewpoint from historical hindsight, and viewpoint related to urban development.

The purposes of this study are to identify the regional characteristics and to examine the influence of Hanyang’s stream network on the administrative area boundaries by comparing it with that of the 1900s.

First, a digital channel network of Joseon is derived using a geographic information system (GIS) by restoring the geomorphological features in the late Joseon period, and the cadastral map of 1912 is prepared as CAD data. Second, the digital drainage system was restored in Joseon’s channel network in the Joseon period and the real water-stream networks in the 1900s are compared to interpret the differences. Third, the impact of urban channel network on the urban spatial structure is investigated by analyzing the effect of the digital drainage system on the establishment of Hanyang’s administrative regions.

The study area is the topography of Hanyang including 24 tributary channels (Park 2006a) flowing down from the inner four mountains surrounding the city which continuously appear in earlier maps and records.

Based on Juncheon-Sasil, Hangyeong-Jiriyak, and Dongguk-Yeoji-Bigo, Park counted 24 streams flowing into rivers flowing into the stream network of the city. The study was carried out first by verifying the natural environment of Seoul’s historical center including topography and soil characteristics as well as the aquatic environment such as watersheds and waterways.

The geomorphology and water gates were analyzed using the datasets thus gained. The terrestrial and aquatic environments formed by tributaries in Seoul’s historical center were restored using the “1:10,000 Joseon Map Compilation” (1915, 1921) and “Gyeongseong Map” (1928). Specifically, the city topography was restored using the “1:10,000 Joseon Map Compilation” of 1921 and refined using the “1:10,000 Joseon Map Compilation” of 1915, thus restoring the 1915 topography, which was named “Restored Map of Seoul 1915” and verified against the Gyeongseong Map of 1928, the oldest and most accurate map of Seoul. All work was done by CAD operations, and geographic/hydrologic analysis was performed using GIS datasets.

Previous studies include Park Hyun-wook’s basic research on Hanseong’s waterways and bridges based on old maps and records (Park 2006b), Enomoto Tadanobu’s study on the modernization of Seoul’s drainage system (Enomoto 2009), Koh Ara’s study on the evolution of Seoul’s waterway covers digital drainage system restoration and the impact of drainage system on administrative division (Koh 2018). This study examines the results of these researches to discuss the upgraded accuracy of digital restoration, the discrepancies in waterways between real contour and earlier maps, and the relationship between drainage system and administrative area boundary.

2. Hanyang’s drainage system

2.1. Contour restoration and digital drainage system of the Joseon period

The four mountains surrounding Hanyang have elevations ranging from 120 to 342 meters, with Baegak in the north standing highest, followed by Inwang in the west (339 m) and Mongmyeok in the south (265 m), and Nakasan in the east being lowest. Despite different heights, their slopes are similarly sharp. Hanyang is surrounded with mountains and hills all around, whereby it opens towards the topographically lower southwestern and eastern areas. All four mountains become lower towards the city core starting from the fortresses. The stream network naturally becomes denser towards the city core (Kil 2017) (Figure 1).

To derive stream network, the contour must be restored. However, there are no existing records of contour maps of the Joseon period. The oldest map is the “1:10,000 Joseon Map Compilation” of 1915, and there are “1:10,000 Joseon Map Compilation” of 1921 and the Gyeongseong Map of 1928, of which the latter shows detailed contour lines. A CAD-based digital map was generated using the “1:10,000 Joseon Map Compilation” of 1915 and 1920, and geomorphic details were corrected using the Gyeongseong Map of 1928.

The GIS work was performed as follows: First, the topography of the city was restored from the “1:10,000 Joseon Map Compilation” of 1921 using CAD and digitized the restored topography after correcting it with the “1:10,000 Joseon Map Compilation” of 1915. Map

Figure 1. Daedongyeo-jido, 1861. (Source: Kyujanggak Institute for Korean Studies).
correction was performed by restoring lost contours and the changed ones due to buildings. Comparison of “1:10,000 Joseon Map Compilation” of 1915 and 1921 and the “Gyeongseong Map” of 1928 allowed the estimation of the changed contour. The Gyeongseong Map (1928) shows a large number of lost contours, which could be restored based on the “1:10,000 Joseon Map Compilation” of 1915 and 1921 (Figure 2).

Second, the restored map (hereinafter the 1915 Computerized Map) was then used for constructing geomorphologic data, namely triangulated Irregular network (TIN)(Lee and Shim 2003a) and digital elevation model (DEM)(Lee and Shim 2003 b), followed by stream network sample extraction for hydraulic/hydrologic analysis (Lee and Shim 2003) (Figure 3).

Third, in the process of topographical reproduction, the current topography and that of the 1915 Computerized Map had to be forcibly overlapped on the basis of the numerical map provided at the portal of the National Spatial Data Infrastructure (www.nsdi.go.kr). The areas with significant differences between the two maps were given coordinates and corrected through interpolation (Lee and Sohn 2016).

Fourth, map correction was performed to match the confluences between the stream and its tributaries with those indicated in historical records, whereby the minimum necessary corrections as the discrepancies in the passage of waterways, attributing them to the topographical changes overtime.

The result of this restoration and correction work is the “Restored contour and streams network in Joseon Dynasty” (Figure 4).

2.2. Stream network according to the cadastral map (1912)

The 1912 Cadastral Map is the first map generated using the modern survey technique in Korea. This cadastral map has no topographic designations, but stream network and road names are indicated. It was therefore possible to derive the stream network by applying CAD operations of the 1912 Cadastral Map (Figure 5) to the
1915 Restored Map. The result of this CAD application is the real water-stream networks in the 1900s (Figure 6).

3. Comparison between the original stream network and the 1900s real stream network

Given that there were no large-scale civil engineering projects that could change contour lines, the thus corrected contour lines fixed on the 1915 map were assumed to represent the actual map of Hanyang in the Joseon period and the digital stream network derived from the 1915 map by GIS operations. In this study, the 1915 Digital Stream Network (Figure 7, blue line) derived as a result of GIS analysis was considered the originally formed stream network in the Joseon period. Likewise, the 1900s Real Stream Network (Figure 7, red line) based on the 1912 Cadastral Map was considered the actual topographical map of late Joseon. As a result of waterway comparison by superposing, the waterways derived by GIS analysis upon those on the 1912 Cadastral Map revealed that most waterways including the origin of each tributary were similar (Figure 8).

Primarily around the Cheonggyecheon Stream, the southern flow paths have not greatly changed, with variations mostly seen in the northern flow paths. It means that an artificial factors were more applied in the northern part than in the southern one. The southern part was developed organically according to a topology. Only in a few locations, altered waterways were observed between the original and 1900s’ stream networks. As causes of such deviations, two factors may be pointed out: (i) flow path changes due to the urban development and the construction of facilities, (ii) terrain changes through human activities.
First, there were two examples for flow path changes due to the urban development and the construction of facilities: (i) Gyeongmo Palace and Heungdeokdong-cheon (Figure 8 ③), (ii) Yukjo avenue establishment and Baegundong-cheon (Figure 8 ②, Figure 9), (iii) Jongno and Angukdong-cheon.

Comparing the flowing path of the Heundokdong-cheon between the real shape and GIS analysis result, the flowing paths in the confluence of eastern and western branches into the Heundokdong-cheon are different. GIS-based confluence is more natural. It could be verified that the flow paths of the eastern and western branches towards the confluence in the Joseon period and those on the 1912 Cadastral Map were artificially changed. The causes of artificial change of flow paths are assumed to be ascribable to the following three factors: (i) Gyeongmo Palace location; (ii) construction of a pond in front of the Gyeongmo palace; (iii) Banchon’s development and expansion.

Baegundong-cheon shows the largest variation when comparing the digital stream network, which represents that of the Joseon period, with that of the 1912 stream network. Its overall shape in the GIS analysis was skewed towards Gyeongbok Palace in deviation from the historical records that it flew along Jahamun-ro. It can be inferred that the original topography changed according to Yukjo avenue in which many administrative institutes had been constructed in front of Gyeongbok Palace at that time. It could make the flow path changed. (Figure 9)

As shown Figure 7, two waterflows crossed Jongro which had been planned as a representative avenue in Joseon Dynasty. So their flow paths might be changed to show the dynasty’s dignity.

There are two examples for flow path changes due to geomorphological changes; (i) flood control: Angukdong-cheon (Figure 8 ⑥) and Hoejong Jesaengdong-cheon (Figure 8 ⑤), (ii) artificial hill- (Gasan) and Namsomundong-cheon (Figure 8 ④).

As shown Figure 7, the Angukdong-cheon originally flew southwards directly from Daesa-dong into the mainstream upstream of Supyu Bridge. However, in order to stop frequent flooding due to sudden inflow increase, the court accepted the proposal of Jeong Jin, the Pan-Hanseong-Busa (corresponding to today’s Mayor of Seoul), in 1421 (the third year of Sejong’s reign) and dug a ditch as a water path along the backside of the market place arrayed in the south-north direction of Jongno on the occasion of a large-scale engineering of stream branches and creeks within the city wall. At that time, Angukdong-cheon was induced to flow along the backside of the southern marketplace and the Howdong Jesaengdong-cheon, which used to flow along Gahoe-dong, was induced to flow eastwards along the backside of the northern marketplace, to join the Changgyeong Palace Okryu-cheon and flow into the mainstream (Park 2006b). Conclusively, the flow path discrepancies of the Angukdong-cheon and Hoejong Jesaengdong-cheon between the digital and real waterways were verified to be the artificial waterway engineering for flood prevention.

A comparison between the digital and real waterways revealed that the flow paths of the Namsomundong-cheon are identical in general with some exceptions. The waterway that used to flow into the stream after being bifurcated at the crossroad of the Gwanghee Gate does not appear in the GIS analysis result. The earth and sand dug out by the dredging of the stream was piled up nearby to form a few hills, which were called Gasan (artificial hills). (Seoul Museum of History 2017) One of these hills changed the original flow path of the Namsomundong-cheon. The bifurcated waterways generated due to the creation of Gasan, not due to natural landform, disappeared as the Gasan disappeared in the 1900s, which explains the geomorphological discrepancies between the real and estimated waterways. (Figure 10)

4. Hanyang’s stream network and the formation of administrative boundaries

(1) Hanyang’s flood control and forest erosion control efforts

The keywords of Hanyang’s urban management were flood control and forest erosion control aimed
at preventing floods and landslides. In the Annuls of the Joseon Dynasty, there are no records of forest erosion control, but flood control is mentioned, mostly pointing out its necessity, giving examples of China.

In the Annuls of King Yeongjo, endeavors about flood control are mentioned. Mountains are steep and rivers short. The water and sediment discharge have a great impact on the scale of flood damage and downstream water usage. So the forest erosion control is an inseparable part of flood control in managing the city of Hanyang.

The city of Hanyang, which is surrounded by four mountains, was formed by the naturally formed mountain system and stream network. According to the Annuls of the Joseon Dynasty, this natural environment frequently cause floods by through discharge of a large amount of water into the upstream areas of the mainstream. To prevent flooding, waterways were induced to flow along detour paths by digging ditches along the backside of the marketplace during the reign of King Sejong. Thus, he implemented city management policies using the natural environment formed by mountains and waterways while adapting to them. As part of forest erosion control and flood control efforts, Sasan-Geumpyo-Do (map of restricted areas

in the four mountains) drawn in 1765 (the 41st year of King Yeongjo), on which areas where burial and logging of pine trees are prohibited are indicated. This demonstrates that forest erosion control is important for flood control and that Hanyang was governed in a manner to maximize safety while adapting to the natural environment.

(1) Administrative boundaries and the stream network

In order to evaluate the correlation between the administrative boundaries (Bang) and the city structure, this research overlapped the administrative boundaries of Hanyang and the urban structure. Hanyang was developed using these two elements while adapting to them.

Figure 11 illustrates the waterways of the 24 tributaries of the mainstream of Hanyang. The blue line represents the stream networks identified by GIS analysis, the gray line represents areas where roads and Bang boundaries coincide, and the red line represents areas in which stream networks and Bang boundaries coincide.

It shows the average match rate between Bang boundaries and other factors. The total circumference of Bang boundaries is 42.6 km. The stream network continues along the Bang boundary for 15.9 km, showing a match rate of 37.4%. Roads also coincide with the Bang boundaries for 19.9 km, showing a match rate of 46.8%. Hanyang was much influenced on by the stream network while many other cities’ administrative boundaries generally coincided to the stream network.
The coincidence of the stream network and the settlements located in them demonstrates that Hanyang was adapted to the given topography to control flood and mountains erosion.

As representative examples, the Samcheongdongcheon(①)(Seoul Museum of History 2015), Namsomundong-cheon(④), Heungdeokdong-chon (③) stream networks and administrative boundaries will be examined. (Figure 8)

The stream network of the Samcheongdong-cheon corresponds to the administrative unit Jingjang-bang, Gwangwang-bang, Jingcheong-bang, and Seorin-bang. The upper-stream areas of the Samcheongdong-cheon, Jingjang-bang and Gwangwang-bang to the north, shared boundaries with those of the Samcheongdong-cheon and the Angukdong-cheon and were developed along the boundary of Yukgok-ro in front of the Gyeongbok Palace. The boundaries of the downstream areas of the Samcheongdong-cheon, centrally located Jingcheong-bang and Seorin-bang, were formed around Jongno and Yukjo avenue, urban planning streets, demonstrating that the flow path of the tributary influenced the district division.

The Namsomundong-cheon area corresponds to the administrative unit Myeongcheol-bang in the Joseon period, and its stream network coincides with MyeongChelbang’s boundaries.

The Heungdeokdong-cheon area corresponds to Sunggyo-bang, Yeonhwa-bang, and Geondeok-bang in the Joseon period. Its stream network boundary partially coincides with the bang boundaries within these three units.

After evaluating the variables that influenced the city structure of Hanyang, Roads showed a match rate of 46.85% and the stream networks showed 37.41% match with the administrative boundaries. This shows that both the roads and the stream networks greatly influenced the city structure of Hanyang. Uch analysis results suggest that natural geomorphological analysis can be an important element of stream network exploration and multifactorial analysis of urban space.

5. Conclusions

This study was conducted to investigate the stream network formed in Hanyang and the topographic features of the surrounding areas for the purpose of identifying the impact of Hanyang’s stream network on its city formation. To this end, three substudies were conducted: (i) Topographic restoration of late Joseon using a digitized map including the stream network of the Joseon period and a cadastral map; (ii) Identification and explanations of the discrepancies between the digitally restored stream network and the real stream network by superposing the former upon the latter; (iii) Identification of the Hanyang’s stream network on its urban structure. The results of this study can be summarized as follows:

First, tributaries’ geomorphological features and watersheds were extracted using the GIS-based hydraulic/hydrologic analysis. The resultant digital stream network was considered the original topography and stream network of the Joseon period. Likewise, the real stream network based on the 1912 Cadastral Map was considered the altered topographical map of late Joseon. The waterways derived by GIS analysis and those on the 1912 Cadastral Map were verified to general coincide with each other, but some altered waterways were observed. This was mainly due to more apparent variations in the northern flow paths than the southern flow paths, centered around Cheonggyecheon Stream. Some changed waterways were observed, presumably due to two factors: (i) flow path changes due to the construction of facilities; (ii) terrain changes through human activities.

Second, the majority of stream networks and roads coincided with administrative boundaries. The city structure of late Joseon was divided into Bang and Gye settlement units. By verifying that these settlement units were formed within the stream network of the tributaries, it could be concluded that Hanyang’s city structure developed adapting to its mountain system and stream network and that settlement location was decided accordingly.

Notes on contributor

Seungwoo Yang studied the German urban form in Germany Otto Friedrich University Bamberg geography with W. Kring in 1998; he studied on the theme of action and urban design in the United States UC Davis Civil Construction in 2007. Currently, Professor Yang operates a Laboratory of Urban Design and Urban Form in the University of Seoul in the urban engineering department. The main concerns are, urban design, urban form, urban planning and carrying out research and projects related to them.

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