

Environmental Impact Assessment for Flemingsbergsdalen

2020-01-16

Foreword

The municipality of Huddinge has formulated an ambitious vision for developing the area of Fleminngsbergsdalen. With the aim of developing a new integrated urban centre with new businesses, commerce, housing and social services, the project entails significant construction work and an intensification of urban activities. This, in turn, can potentially lead to substantial environmental impacts.

The present report is an assessment of the potential environmental impacts of the Flemingsbergsdalen development. The assessment and report were produced by students of the masters' level course *Case Studies in Environmental Impact Assessment* at Stockholm University.

The Environmental Impact Statement presented here is the result of rigorous research by the students during a period of six weeks between December 2019 and January 2020. The results and views presented in this report are those of the students alone, and do not represent the position of Stockholm University. We would like to acknowledge all who have offered help and input during this process.

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List of Acronyms

CBD	Central Business District
CLD	Causal loop diagram
CO_2	Carbon dioxide
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EQS	Environmental Quality Standard
ESS	Ecosystem Services
EU	European Union
GI	Green Infrastructure
IT	Information Technology
LED	Light emitting diode
NGO	Non-governmental organisation
NO_2	Nitrous Oxide
Nox	Nitric oxide and nitrogen dioxide
PAH	Polyaromatic hydrocarbons
PCB	Polychlorinated biphenyls
PM_{10}	Particles less than 10 µm
PPE	Personal Protective Equipment
RUFS 2050	Regional Development Plan for the Stockholm Region 2050
SLB	Svenska Luftlaboratoriet
SME	Small and medium-sized enterprises
SMHI	Swedish Meteorological and Hydrological Institute
SO_2	Sulfur dioxide
WHO	World Health Organisation
VOC	Volatile organic compound

Units

dBA	A-weighted value describing the sound in decibel
kPa	Kilopascals
ha	Hectare

Glossary

Aerosols	Fine solid particles in the air; natural or anthropogenic.
Anthropogenic	Something created, altered, or directly/indirectly caused by humans.
Biodiversity	The variety of flora and fauna found in the study area.
Catchment basin	A topographic region in which all precipitation falling within said region drains to a common outlet point.
Disparity	A noticeable difference based on a lack of equality and similarity.
Ecosystem services	Products and services produced by natural ecosystems, that directly or indirectly contribute to human survival and quality of life.
Eutrophication	The over-enrichment of nutrients and minerals in a body of water (*sv. övergödning*).
Gentrification	The process of renovating and improving a district, originally occupied by the working-class. By changing the social character of the district through the moving in of wealthier residents and businesses, the original residents are potentially displaced.
Green roofs	Roofs that are covered with vegetation (partially or completely). These are implemented as nature-based solutions in dealing with stormwater.
Habitat	A natural, living environment for a species.
Habitat fragmentation	Decomposition of a habitat into smaller areas
Habitat nibbling	Gradual loss and/or fragmentation of habitats (Treweek, 2009).
Heat islands	Describes built up areas that are hotter than nearby areas due to human activities.
Hydraulic conductivity	Measure of the ease with which water flows through sediments.
Infiltration	The process in which water flows from the ground surface into the (sub)surface, soil, or rock.

Percolation	Fluids passing through porous material or small holes; mostly refers to the movement and filtering of water.
Permeability	The ability of porous material (often rocks, loose material, or soil) to allow fluids to pass through it.
Recipient	In hydrology, the recipient is the receiver of discharging water from a specific catchment. In this specific project, it is referred to as the Flemingsbergsvikens wetland-complex and Lake Orlången.
Red-listed species	The International Union for Conservation of Nature lists threatened species that face the risk of extinction.
Retention basin	See “Stormwater pond”
Runoff	The movement of fallen rain (or the substances carried in it) flowing or draining from the surface of one area to other areas.
Sedimentation pond	See “Stormwater pond”
Segregation	The action of setting someone or a group of individuals apart from others, due to ethnicity, race, sex, gender, religion or political motivation.
Stormwater	All water that originates from precipitation, both in the form of rain and snow. Stormwater can later be partitioned as surface water and groundwater. (*sv. dagvatten*)
Stormwater pond	Used as an artificial basin for stormwater management to deal with runoff, prevent flooding, and improve water quality in the recipient. Other commonly used synonyms are retention basin and sedimentation pond. (*sv. dagvattendam*)
Surface water	Water accumulating on the ground’s surface. This can include any body of water on the earth’s surface, such as streams, rivers, ponds, lakes, wetlands, reservoirs, and creeks.
Till	Material deposited by glacial ice, accumulating and forming a moraine.
Toolbox talks	A toolbox talk is an informal group discussion that focuses on a particular safety issue. These tools can be used daily to promote department safety culture as well as to facilitate health and safety discussions on job sites (Harvard, 2015).
Water table	Equivalent to ground water level.

Non-Technical Summary

Background

The Flemingsbergsdalen city centre is one of the eight “regional city centres'' identified in the RUFS 2050 development plan. These regional city centres act as international, national, regional, and sub-regional hubs, due to their location and particularly high regional accessibility within the transport network. Consequently, the Flemingsberg development planning program has been conducted. This provides a framework for planning conditions and continued development objectives within the area until 2050. Although, it is yet to be approved and the approval date is anticipated to be in April 2020. The construction is proposed to last approximately 10 years after approval and will transform today's Flemingsberg into an urban centre for education and creativity by 2050. Unlike the northern municipalities of Stockholm, Flemingsberg and the rest of southern Stockholm do not have an active business district. This has caused an unbalanced flow of goods and people between the south to the north of Stockholm. Therefore, developing a new business centre in the south of Stockholm could relocate these flows and help people find work closer to home. This development could cut down on commuting time but also encourage the use of public transport.

Proposed Project Description

The municipality predicts that the new business centre will promote local growth and potentially boost the area’s economy. The vision is to have a living city every hour of the day and be able to deliver urban qualities close to the residents such as new workplaces, public transport and other public areas where people can meet for social events with the development of entertainment centres. The proposed vision for Flemingsberg is to develop a city centre that will accommodate approximately 5 000 new residents and 35 000 new workplaces.

The Flemingsbergsdalen project is divided into six phases (Figure A1) with different developmental aspects and purposes that contributed to the area as a whole. However, these were assessed as four phases in the report (Table A1).

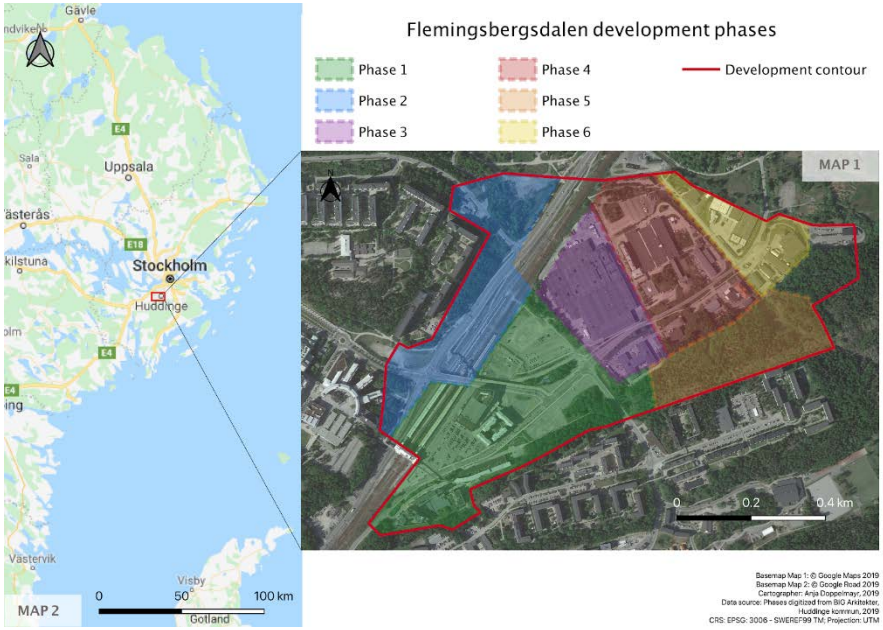


Figure A1*. Development site and construction phases within Flemingsberg, Huddinge kommun south of Stockholm City, Sweden (BIG Arkitekt, Google Maps, Google Road; Illustrated by Doppelmayr, A., 2019).*

***Table A1**. The different phases are described in this table.*

Phase 1: City Centre	Include residential apartments, public service centres, business offices, a shopping complex and a variety of entertainment centres such as sport, events, cultural and leisure centres.
Phase 2: Overlay Development	Consists of a new travel centre which will be the public transport hub including commuter trains, long distance trains, busses and trams.
Phase 3-4: Residence Area	Will have approximately 3 000 densely built residential apartments combined with offices on the lower levels of varying heights to create a mixture of a modern international urban feel with local accents.
Phase 5-6: Recreational Parks and Schools	Mainly comprises of green parks for recreation, preschools, schools and residential areas.

The renewal of the Flemingsbergsdalen area and the generation of a regional city centre was the subject of this Environmental Impact Assessment (EIA). This report will identify, map and evaluate potentially harmful actions during the development of the new city centre, which could affect humans, society or the environment.

Baseline Environment and Current Land Use

The district was the project is supposed to be built is currently dominated by businesses, residential areas and public workplaces, including health care, higher education, research, and justice facilities. There are 15 000 inhabitants and 15 000 workplaces in Flemingsberg today. There is a barrier that divides the area into two parts because of the railway and Huddingevägen. Flemingsberg is identified to have issues with socio-economic segregation and inequalities. The city of Flemingsberg is well connected to both the Stockholm region and Stockholm city through trains, easily accessible by car, and well-served by busses. As a consequence of the current traffic volume, high levels of noise have been recorded. There are no areas with high natural values in the proposed project area. However, Flemingsbergs nature reserve lies within close proximity to the project area, along with Lake Orlången. Some soil contamination has been detected in the project area. Additionally, stormwater management has reached its maximum capacity.

Alternatives Considered

The Planned Project

Overall, the construction period was likely to generate more negative effects, as compared to afterwards when the city centre is built, which had generally more positive effects. Also, the natural environment indicators were generally more negatively affected compared to the socio-economic indicators, which were more positively affected (Table A2).

The indicator *cultural heritage* was graded as being susceptible to big negative effects. However, it was limited to the specific Phase 3-4. Therefore, it was not classified as the most important indicator. The indicators which have been evaluated as most important and were susceptible to large negative effects (and were common for all phases) were *air quality, surface-, and groundwater, soil*, and *noise*. The indicators which would be largely positively affected were *recreation, accessibility*

and connectivity, and *equality*. Despite biodiversity being estimated to having low importance within the project area, the indicator was estimated to be largely affected in Flemingsbergs nature reserve and Lake Orlången.

***Table A2**. How different indicators will be affected by different action taken for the Planned Project (see page 140 for full size).*

		Construction Phase				Operation Phase						
	Actions / Environmental Indicators	Construction of infrastructure	Movement of land	Demolition of buildings and removal of infrastructure	Exploiting unused areas	Public facilities	Commercial buildings	Residential buildings	Waste generation	Sealed surfaces	Traffic	Parks and green spaces
Natural	Biodiversity	- -	- -		- -	-	-	-			-	+
	Air (quality)	-	-	-	-	+ / -	+ / -	+ / -			--	+ +
	Surface water	- -	- -	- -	- -	+	+	+		- -	- -	+ +
	Ground water	- -	- -	- -	-					-	-	+
	Noise	-	-	-	-					-	- -	+
	Soil	-	- -		-						- -	- -
Cultural	Cultural heritage	- -	- -	- -	-						-	-
	Visual landscape	-	-	-	-	+ +	+ +	+ +				+ +
Socio-Economic	Housing	-	-	-		+ +	+ +	+ +				
	Recreation	-	-	-	-	+ +	+ +	+ +		+ +		+ +
	Health	-	-	-	-	+ +	+ +	+ +		+ / -	+ + / -	+ +
	Safety	-	-	-	-	+ +	+ +	+ +			+ + / -	+
	Equality					+ +	+ +	+ +			+	+
	Employment	+	+	+		+	+ +				+	
	Accessibility and Connectivity	-	-	-	-	+ +	+ +			+ +	+ +	+

Plus Alternative

The aim of the Plus Alternative is to reduce the pressure that the Planned Project would have on biodiversity and Lake Orlången. With the Plus Alternative around 15 small-scale apartment buildings from Phase 5 and the northern corner of Phase 2, will be added on top of the planned buildings in the other phases to still reach the development goal until 2050.

***Table A3**. How different indicators will be affected by different actions taken for the Plus Alternative. The striped cells indicate a change in impact as compared to the Planned Project Alternative (see page 158 for full size).*

		Construction Phase				Operation Phase						
	Actions / Environmental Indicators	Construction of infrastructure	Movement of land	Demolition of buildings and removal of infrastructure	Exploiting unused areas	Public facilities	Commercial buildings	Residential buildings	Waste generation	Sealed surfaces	Traffic	Parks and green spaces
Natural	Biodiversity	-	-			-	-	-			-	+
	Air (quality)	-	-	-	-	+ / -	+ / -	+ / -			- -	+ +
	Surface water	- -	- -	- -	- -	+	+	+		+	- -	+ +
	Ground water	- -	- -	- -	-					+	-	+
	Noise	-	-	-	-					-	- -	+ +
	Soil	-	- -		-						- -	- -
Cultural	Cultural heritage	- -	- -	- -	-						-	-
	Visual landscape	-	-	-	-	+ +	+ +	+ +				+ +
Socio-Economic	Housing	-	-	-		+ +	+ +	+ +				+
	Recreation	-	-	-	-	+ +	+ +	+ +		+ +		+ +
	Health	-	-	-	-	+ +	+ +	+ +		+ / -	+ + / -	+ +
	Safety	-	-	-	-	+ +	+ +	+ +			+ + / -	+
	Equality					+ +	+ +	+ +			+	+
	Employment	+	+	+		+	+ +				+	
	Accessibility and Connectivity	-	-	-	-	+ +	+ +			+ +	+ +	+

With the Plus Alternative there would be less impact on biodiversity during construction phase in comparison with the Planned Project, because the land areas which were originally intended for Phase 5 and 2, would be left unexploited (Table A3). This would also have a positive effect on noise; by keeping the forest area intact, this would prevent city sounds to travel. The result of building even taller buildings could affect the higher storeys in a sense that reflection of sound from sealed surfaces and buildings can directly expose higher floors. As the area of sealed surfaces would not

decrease immensely, these areas will still contribute to noise pollution similar to the Planned Project. By keeping Phase 5 untouched, in comparison with the Planned Project, the green spaces will constitute a larger area in the Plus Alternative. Having the forest area close to the new residential area could create attractiveness for the people living there.

The surface- and groundwater would have the same impacts during construction phase. By keeping Phase 5 and parts of Phase 2 untouched, the proportion of infiltration surfaces would be bigger in comparison with the Planned Project. This would mean that the wetland-complex could have better conditions for receiving an increase of runoff in the future.

Zero Alternative

The Zero Alternative examined how the natural, cultural and socio-economic environment in this area would change if the Planned Project were not to be developed in the future.

There would be no exploitation of the natural areas with the Zero Alternative and therefore there will be no effect on the biodiversity. Lake Orlången is today contaminated, but the status has improved in recent years and could, with the Zero Alternative, have a chance to be even more improved in the future. But at the same time, the existing solution of the drainage system is barely enough to handle the current stormwater in the area. With the increase of heavy rainfall from climate change, this system would therefore not be sufficient enough in the future.

As mentioned in the baseline, Flemingsberg has problems with socio-economic segregation and inequalities. With the Zero Alternative, there would be no major beneficial developments in this area. The urban structure of this area would basically be the same, except from some smaller developments. Without the development there will be hardly no new job opportunities, social meeting spots and the urban structure would still be characterised by the railway that divides the centre.

Cumulative Impacts

One impact alone can have a small effect, but together with other impacts, these can accumulate and the once small impact can instead have devastating effects on the environment; this is the cumulative impact.

There will be a parallel development of two projects in Flemingsberg region; Tvärförbindelse Södertörn (new road) and Spårväg syd (new tram line). To put these projects into a wider perspective, the impacts were viewed on a regional and global scale.

The indicators of greatest concern were concluded to be noise and air pollutants. All three projects were believed to affect the air quality through the production of greenhouse gases and other particles. These emissions conflict with Sweden's goal to reach net-zero by the year 2045. To reach both the projects own ambitious goals and Sweden's environmental goals, cumulative impacts would need to be addressed. Currently, the projects combined impacts are not predicted to succeed with this task.

Climate Change

The future climate in Flemingsberg is predicted to be warmer with more precipitation and changed water flows. The future city Flemingsbergsdalen could be affected, both the buildings and the humans who will live there. High temperatures could affect the health risk for elderly and children but also increase the risk of infection spreading. Increased precipitations

causing an increase in moisture, and therefore risk for mold damage on buildings, and flooding that might affect the infrastructure. With climate change in mind, the impacts from stormwater could therefore be greater than expected, and this is important to consider and plan for when a new city centre is being built.

Mitigation

Mitigation measures are actions taken to prevent or minimise the effects from certain impacts. The most important mitigation measurements that were suggested, were derived from the Planned Project, and focused on the effects from noise, air pollution and stormwater.

In order to reduce noise pollution, control and prevention should be done at the source. During construction, temporary walls with noise absorbing material could be used, and machines and methods with low noise generation are preferred. Construction should also be limited to certain hours of the day, to minimise disturbance. The human exposure of air pollutants could be regulated by planting hedges between city streets and walking pathways. Green roofs and facades covered in vegetation also absorbs particles, minimises the exposure, and reduce noise. Construction should also be planned to not take place during windy or exceptionally dry days. For managing stormwater, several vegetated solutions were proposed; vegetated open ditches and plantation of trees and bushes may not only clean the water, but also retain water in areas with low permeability. Special type of soils was also proposed to be used in order to aid the purification of stormwater. Parks and other green areas should be located in areas with most suitable soil types to enhance the ability to absorb and retain water. Additionally, it was stressed that the stormwater pond located northeast of the project area was to be built and dimensioned to be able to handle large quantities of water early in the construction phase.

Monitoring

Monitoring should be done to determine if guideline levels are followed. It was recommended to set up a monitoring system that could complement and control mitigation measures and monitor the general status of the environment. The indicators that were recommended to be monitored is stormwater, noise -, and air pollutants.

Closing Remarks

In order to accomplish the vision and goals of having a cultural, social and flourishing city centre, providing the Flemingsbergs inhabitants a basis for work, education and recreation, both the Planned project and the Plus Alternative suggested here can accomplish these goals. However, there is a large emphasis to take segregation, stormwater management and future climate change in consideration for the future planning of Flemingsbergsdalen.

Icke-Teknisk Sammanfattning

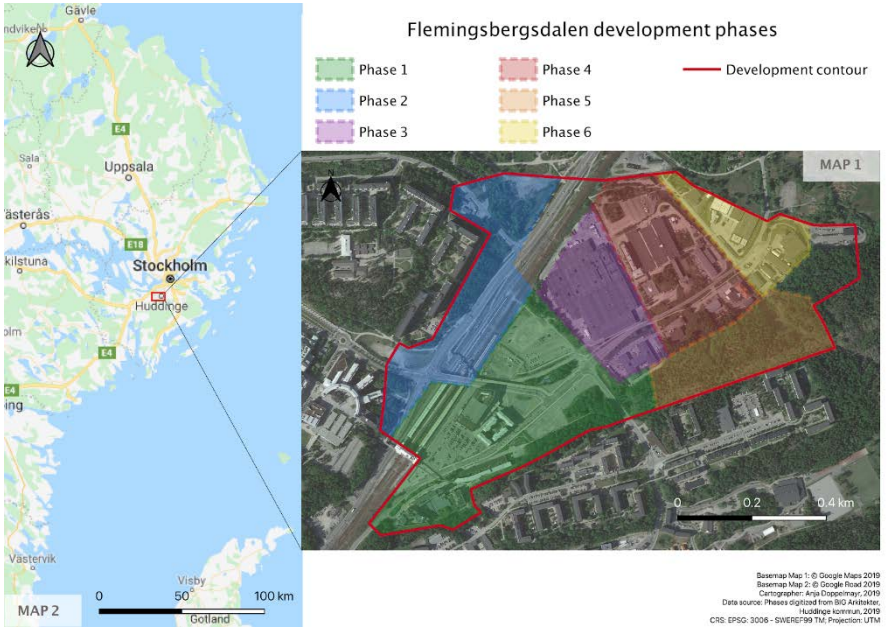
Bakgrund

Stadsdelen Flemingsbergsdalen är en av åtta regionala stadskärnor som är identifierade i RUFS 2050 utvecklingsplan. De regionala stadskärnorna fungerar som internationella, nationella och regionala centrum, på grund av deras placering och särskilt höga regionala tillgänglighet inom transportnätet. I planprogrammet för Flemingsbergsdalen finns utvecklingsmål och visioner för hur stadsdelen ska utvecklas till år 2050. Planprogrammet förväntas godkännas i april 2020 och ombyggnationerna förväntas pågå i minst 10 år. Byggnationerna kommer göra Flemingsberg till ett urbant centrum för utbildning och kreativitet år 2050. Till skillnad från kommunerna i norra Stockholm har Flemingsberg och resten av södra Stockholm inte ett aktivt affärsdistrikt. Detta har orsakat obalanserade flöden av varor och människor mellan södra och norra Stockholm. Ett nytt affärsområde i södra Stockholm skulle kunna ändra detta flöde och göra att människor kan arbeta närmare hemmet. Detta skulle även kunna minska pendlingstiden och uppmuntra användningen av kollektivtrafik.

Projektbeskrivning

Huddinge kommun förutspår att ett nytt kontorsdistrikt kommer öka tillväxten och främja områdets ekonomi. Visionen är att ha en levande stad dygnet runt och samtidigt leverera en storstadsupplevelse till invånarna. Projektet planeras skapa nya arbetsplatser, kommunaltrafik och gemensamma mötesplatser där människor kan mötas för sociala tillställningar och fungera som evenemangscentrum. Den föreslagna visionen för Flemingsberg är att etablera en stadskärna som ska rymma cirka 5 000 nya bostäder och 35 000 nya arbetsplatser.

Projektet Flemingsbergsdalen är uppdelat i sex olika etapper (Figur B1) som var och en har olika syften, dessa etapper utgör projektet i sin helhet. I rapporten behandlades etapperna som fyra olika etapper (Tabell B1).



Figur B1. *Projektområde och etappindelning inom Flemingsberg, Huddinge kommun söder om Stockholm City, Sverige (BIG Arkitekt, Google Maps, Google Road; Illustrerad av Doppelmayr, A., 2019).*

Tabell B1. *De olika etapperna i projektet beskrivs översiktligt i denna tabell.*

Etapp 1: Stadskärna	Består av arbetsplatser, service, nöjen och handel och kommer att bli Flemingsbergs stadscentrum.
Etapp 2: Överdäckning	Består av ett nytt resecentrum för kollektivtrafiken och en överdäckning av Huddingevägen och järnvägen.
Etapp 3-4: Bostäder	Består av cirka 3000 bostadslägenheter i kombination med kontor på de lägre våningsplanen. Byggnaderna planeras att variera i höjd för att skapa en dynamisk stad.
Etapp 5-6: Parker och skolor	Består i huvudsak av gröna parker för rekreation, förskolor, skolor och bostadsområden.

Syftet med denna miljökonsekvensbeskrivning är bedöma de konsekvenser som ombyggnationen av Flemingsbergsdalen och utvecklingen av ett regionalt center har på den naturliga- och socioekonomiska miljön. Rapporten har identifierat, kartlagt och utvärderat de potentiellt skadliga handlingarna från ombyggnationen av den nya stadskärnan kan ha på människor, samhället och miljön.

Grundförutsättningar och Befintlig Markanvändning

Området där den nya stadsdelen planeras består i dagsläget av företagsbyggnader, bostadsområden och offentliga arbetsplatser, med närliggande sjukhusområde, högskola och tingsrätt. Det finns 15 000 invånare och 15 000 arbetsplatser i Flemingsberg idag. Huddingevägen och järnvägen fungerar idag som en barriär och delar Flemingsberg i två delar. Flemingsberg har identifierats ha problem med socioekonomisk segregering och ojämlikheter. Det är i dagsläget enkelt att ta sig till och från Flemingsberg med både kollektivtrafik och bil. På grund av den stora trafikbelastningen har höga bullernivåer uppmätts i området. Inom det planerade projektområdet saknas områden med höga naturvärden, däremot finns höga naturvärden i Flemingsbergs naturreservat som gränsar till området. Det har uppmätts föroreningar i marken som skapats genom tidigare industriverksamhet. Dagvattenhanteringen i området har i dagsläget nått sin maxkapacitet.

Behandlade Alternativ

Det Planerade Projektet

Konstruktionsfasen bedömdes ha större negativ inverkan på den naturliga miljön, jämfört med driftfasen, som visade på mer positiva effekter. Indikatorerna rörande naturmiljön var generellt mer negativt påverkade i jämförelse med de socioekonomiska indikatorerna, som till största del hade positiv påverkan (se tabell B2). Indikatorn rörande *kulturarv* klassades som mycket negativ, men det var endast kopplat till den specifika etappen 3-4, och ansågs därför inte vara en av de viktigaste indikatorerna. De indikatorer som har utvärderats till att vara de viktigaste, med störst negativa effekter, och som var gemensamma för alla etapper var *luftkvalitet, yt- och grundvatten, jord* och *buller*. De indikatorer som påverkades mycket positivt av projektet var *rekreation, tillgänglighet* och *jämlikhet*. Trots att den *biologiska mångfalden* uppskattades ha låg betydelse inom projektområdet, beräknades indikatorn påverkas mycket negativt på grund av att Flemingsbergs naturreservat och Orlången togs med i beräkningen.

***Tabell B2**. Hur olika indikatorer påverkas av olika handlingar som utförs i projekt alternativet (se sida 140 för full storlek).*

		Byggnationsfas				Driftfas						
	Miljö indikator \ Handling	Konstruktion av infrastruktur infrastructure	Movement of land	Rivning av byggnader och borttagning av infrastruktur	Utnyttjar oanvända områden	Offentliga lokaler	Kommersiella byggnad	Bostads byggnader	Avfallsgenerering	Tätade ytor	Trafik	Parker och gröna ytor
Natur	Biodiversitet	- -	- -		- -	-	-	-			-	+
	Luftkvalitet	-	-	-	-	+	+	+			--	+ +
						-	-	-				
	Ytvatten	- -	- -	- -	- -	+	+	+		- -	- -	+ +
	Grundvatten	- -	- -	- -	-					-	-	+
	Ljud	-	-	-	-					-	- -	+
	Jord	-	- -		-						- -	- -
Kultur	Kulturellt arv	- -	- -	- -	-						-	-
	Visuellt landskap	-	-	-	-	+ +	+ +	+ +				+ +
Socio-Ekonomisk	Boende	-	-	-		+ +	+ +	+ +				
	Rekreation	-	-	-	-	+ +	+ +	+ +		+ +		+ +
	Hälsa	-	-	-	-	+ +	+ +	+ +		+	+ +	+ +
										-	-	
	Säkerhet	-	-	-	-	+ +	+ +	+ +			+ +	+
											-	
	Jämnställdhet					+ +	+ +	+ +			+	+
	Sysselsättning	+	+	+		+	+ +				+	
	Tillgänlighet	-	-	-	-	+ +	+ +			+ +	+ +	+

Plusalternativet

Syftet med Plusalternativet var att minska trycket på biodiversiteten och sjön Orlången som det Planerade Projektet skulle medfört. Med Plusalternativet minskades area på projektområdet då exploatering av Etapp 5 och de norra delarna av Etapp 2 exkluderades. Samtidigt innebar Plusalternativet att samma antal lägenheter skulle produceras för att nå utvecklingsmålet till 2050. Det innebar att resterande etappers fastigheter skulle få ett högre våningsantal.

Plusalternativet utgav en lägre påverkan på biodiversitet under konstruktionsfasen i jämförelse med det Planerade Projektet eftersom Etapp 5 och norra delarna av Etapp 2 behålls oexploaterade (Tabell B3). Genom att bibehålla ett intakt skogsområde förhindras stadsbuller att spridas. Även om antalet våningar ökade skulle buller från gaturummet ha en fortsatt påverkan på de högre belägna våningarna.
Andelen hårdgjorda ytor i gaturummet skulle vara densamma som för det Planerade Projektet, dock skulle en högre konstruerad stad generera ytterligare bullerpåverkan. Genom att hålla Etapp 5 oexploaterad erhöll Plusalternativet en större yta med grönområden än det Planerade Projektet, vilket i sin tur kunde attraktiviteten för människorna som skulle leva och bo i dessa områden.

Påverkan på yt-, och grundvattnet skiljde sig inte åt mellan de olika alternativen. Genom att bibehålla området för Etapp 5 och norra delarna av Etapp 2 skulle dock proportionen infiltrationsbara ytor att vara större i jämförelse med det Planerade Projektet. Det medförde att förutsättningarna för våtmarksområdet skulle förbättras och därmed kunde ökade mängder av dagvatten i framtiden bli mer hanterbart.

***Tabell B3**. Hur olika indikatorer påverkas av olika handlingar för Plusalternativet. De linjerade rutorna indikerar på att påverkan förändrats i jämförelse med projektet (se sida 158 för full storlek).*

		Byggnationsfas				Driftfas						
	Handling / Miljö indikator	Konstruktion av infrastruktur infrastructure	Movement of land	Rivning av byggnader och borttagning av infrastruktur	Utnyttjar oanvända områden	Offentliga lokaler	Kommersiella byggnade	Bostads byggnader	Avfallsgenerering	Tätade ytor	Trafik	Parker och gröna ytor
Natur	Biodiversitet	-	-			-	-	-			-	+
	Luftkvalitet	-	-	-	-	+ / -	+ / -	+ / -			- -	+ +
	Ytvatten	- -	- -	- -	- -	+	+	+		+	- -	+ +
	Grundvatten	- -	- -	- -	-					+	-	+
	Ljud	-	-	-	-					-	- -	+ +
	Jord	-	- -		-						- -	- -
Kultur	Kulturellt arv	- -	- -	- -	-						-	-
	Visuellt landskap	-	-	-	-	+ +	+ +	+ +				+ +
Socio-Ekonomisk	Boende	-	-	-		+ +	+ +	+ +				+
	Rekreation	-	-	-	-	+ +	+ +	+ +		+ +		+ +
	Hälsa	-	-	-	-	+ +	+ +	+ +		+ / -	+ + / -	+ +
	Säkerhet	-	-	-	-	+ +	+ +	+ +			+ + / -	+
	Jämnställdhet					+ +	+ +	+ +			+	+
	Sysselsättning	+	+	+		+	+ +				+	
	Tillgänglighet	-	-	-	-	+ +	+ +			+ +	+ +	+

Nollalternativet

Nollalternativet undersökte hur det kulturella-, socioekonomiska- och naturliga miljön kan förändras i framtiden om det Planerade Projektet inte genomfördes.

Den biologiska mångfalden ansågs inte påverkas i Nollalternativet eftersom naturområdena inte exploateras. Orlången är idag förorenad men statusen har förbättrats under de senaste åren och med Nollalternativet kan en fortsatt förbättring av dess status möjliggöras. Samtidigt är den befintliga lösningen av dagvattenhanteringen i området knappt tillräckligt. I och med den förväntade ökningen av kraftig nederbörd från klimatförändringar ansågs nuvarande hantering av dagvatten vara otillräckligt i framtiden.

Som nämndes tidigare i *grundförutsättningar och befintlig markanvändning*, har Flemingsberg problem med socioekonomisk segregation och ojämlikhet. Situationen förväntades inte ändras eftersom Nollalternativet innebär att den urbana strukturen i stort sett skulle vara oförändrad i framtiden, bortsett från några mindre utvecklingsprojekt. Utan vidare utveckling av området skulle antalet arbetstillfällen och möjligheter till nya sociala mötesplatser stagnera. Den befintliga barriär som skapar en uppdelning av Flemingsbergs centrum hade fortfarande varit ett problem i stadsstrukturen.

Kumulativa Effekter

Även om en påverkande faktor i sig bara genererar en liten effekt på sin omgivning, kan den i kombination med andra faktorer öka i styrka. Det som en gång varit ofarlig och setts som en obetydlig effekt kan växa till sig och leda till förödande påverkan på sin miljö, detta kallas kumulativa effekter. Det finns två planerade projekt i Flemingsberg som kommer att byggas ungefär samtidigt som Flemingsbergsdalen; Tvärförbindelse Södertörn (ny väg) och Spårväg Syd (ny spårvägslinje). För att se vad dessa tre projekt tillsammans har för påverkan på miljön undersöktes dessa på en regional och global skala.

Indikatorerna buller och luftkvalitet bedöms ha störst påverkan på miljön. Samtliga nämnda projekt tros påverka luftkvaliteten genom produktion av växthusgaser och partiklar. Dessa utsläpp strider mot Sveriges mål att nå noll nettoutsläpp av växthusgaser år 2045. För att både uppnå projektets egna mål och Sveriges mål är det viktigt att inkudera de kummulativa

effekterna. I dagsläget uppnås inte målen om man beaktar de gemensamma effekterna.

Klimatförändringar

Det framtida klimatet i Flemingsberg är förutspått att bli varmare med mer nederbörd och ändrade vattenflöden. Den framtida staden, Flemingsbergsdalen, kan komma att påverka både byggnaderna men också de människor som kommer att bo där. Höga temperaturer kan påverka hälsan hos äldre och barn, men också öka risken för spridning av infektioner. Ökade nederbördsmängder ökar risken för översvämningar som kan ge fukt och vattenskador i och på byggnader, men även infrastrukturen kan påverkas av översvämningar. Det är viktigt att ha klimatförändringarna och dess effekter i åtanke när en ny stadsdel planeras.

Förebyggande Åtgärder

Förebyggande åtgärder innebär att förhindra eller minimerar skadliga effekter som kan uppkomma vid t.ex. exploatering och andra infrastrukturprojekt. De allra viktigaste förebyggande åtgärderna som föreslogs var kopplade till det planerade projektet och fokuserade på att minska effekterna av buller, luftföroreningar och dagvatten. För att kunna minska buller måste kontroller och förebyggande åtgärder göras direkt vid källan. Under konstruktionsfasen bör temporära bullerplank sättas upp gjorda av ljudabsorberande material och använda maskiner och andra byggtekniker som genererar så lite ljud som möjligt är att föredra. Själva byggnadsarbetet bör vara begränsat till vissa tider på dygnet för att minimera störningar på människor som bor i området. Det är även viktigt att ta hänsyn till missgynnsamma väderförhållanden under byggnationen eftersom detta kan ha påverkan på luftkvalitén.

Genom att plantera buskar mellan gator och gångvägar kan exponeringen av luftföroreningar minska. Gröna tak och fasader bidrar också till att minimera exponeringen genom att absorbera partiklar, samt att minska buller. För att hantera dagvatten har flera förslag baserade på att plantera växter, bland annat diken med vegetation samt plantering av träd och buskar. Dessa åtgärder skulle inte enbart rena dagvattnet utan också hålla kvar det i områden med låg infiltrationsförmåga. Användningen av en viss typ av konstgjord jordart föreslogs för att kunna hjälpa till att rena dagvattnet. Parker och andra grönområden bör anläggas i områden med bäst anpassade jordtyper för att kunna absorbera och fördröja vatten inom projektområdet. Som en förebyggande åtgärd betonades vikten av att den planerade dammen i den nordvästra delen av området anlades på ett sådant vis att dimensionen på dammen kan hantera de stora mängder vatten som förväntas tas emot tidigt under konstruktionsfasen.

Övervakning och Uppföljning

För att fastställa att riktlinjer följs bör övervakning av projektet genomföras. Det rekommenderas att man inrättar ett övervakningssystem som kompletterar och kontrollerar olika påverkansfaktorer, exempelvis dagvatten, buller och luftföroreningar.

Slutord

Både det Planerade projektet och Plusalternativet kan uppnå de visioner och mål som skildras i Flemingsbergsdalens planprogram om en kulturell, social och blomstrande stadskärna som kommer bistå Flemingsbergsborna med arbetstillfällen, utbildning och rekreation. Det är däremot viktigt att ta hänsyn till segregation, dagvattenhantering och klimatförändringar under fortsatt planering av Flemingsbergsdalen.

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Part 1: Introduction



1. Introduction to the project

"The Stockholm region is one of Europe's fastest growing metropolitan regions. By 2050, the population of Stockholm County is expected to have grown to around 3.4 million residents" (RUFS 2050, 2017).

Stockholm County currently has approximately 2.4 million inhabitants (SCB, 2019a) and is one of Europe's most successful regions (RUFS 2050, 2018). The rapid population growth in the area, however, brings challenges for development planning. Cooperation on an inter-regional basis is necessary to enhance competitiveness and adapt to a changing climate. Four main regional goals have been set for Stockholm County, which are covered in the regional development plan for the Stockholm region, RUFS 2050. These consist of broad objectives which work toward common goals, such as accessibility and the creation of attractive living environments and ensuring open, equal, and inclusive regions. These goals address the strengthening of growth in innovation and knowledge industries and the promotion of resource efficient and resilient regions that operate without impacting climate emissions. (RUFS 2050, 2017)

The development plan identifies eight "regional city centres,'' which have a very specific purpose within Stockholm County. They are to act as international, national, regional, and sub-regional hubs, because of their location and particularly high regional accessibility within the transport network of eastern central Sweden. Furthermore, each regional city centre is to attract different industries and businesses, therefore complementing each other in terms of diversity (Huddinge kommun, 2019a).

In line with one particular goal of RUFS 2050, one of the regional city centres is to be developed in Flemingsberg, which is located between the municipalities of Huddinge and Botkyrka. Flemingsberg is an important junction for commuter, regional, and long-distance trains (RUFS 2050, 2018).

The Huddinge Municipality, Botkyrka Municipality, and Stockholm County Council have developed and issued a development program for Flemingsberg. The program provides a framework for planning conditions and continued development objectives within the area until 2050. Within this development program, five goals with interim targets have been set, one of which is the development of an urban and diverse city centre with a unique identity (Huddinge kommun, 2019a). The renewal of the Flemingsbergsdalen area and the generation of a regional city centre is the subject of this Environmental Impact Assessment.

1.1 Aim of EIA

An Environmental Impact Assessment (EIA) examines the environmental consequences of a development action. It is both a planning tool and instrument for sustainable development. In general, EIAs constitute directives for developers and provide a framework for decision-makers and planning authorities. The process entails thorough investigation, the consideration of preventative measures for potentially harmful impacts, and the identification of possible benefits and their significance for the social, economic, and physical environment (Glasson and Therivel, 2019).

The present EIA will analyse the development project Flemingsbergsdalen, which is based on the objective of RUFS 2050 and the development program for Flemingsberg for 2050 (RUFS 2050, 2018; Huddinge kommun, 2019a). The purpose of development will be addressed in *Section 1.2: Project Description*. The current status of the environment within and around the project area is described under *Section 1.3: Site Description and Baseline Conditions*. Emphasis will be put on planned actions for each phase and the identification of potential impacts, derived from such actions and associated activities. Additionally, the focus of the EIA will be set on the evaluation of significant impacts to illustrate the consequences of particular actions. It is crucial to identify likely affected environmental components and stakeholders, especially where significant impacts are non-negotiable or not acceptable, in order to provide appropriate mitigating measures and suggest suitable alternatives to counteract these impacts.

As of today, no EIA has been carried out for the Flemingsbergsdalen project. According to Gregorsson, the plan program will be approved by April 2020 (2019, Personal correspondence). Thus, the project is in an early stage, where consultation and public participation play an integral role. It is crucial to consider all participatory comments and suggestions, as the purpose of an EIA is to include the public, provide them with information, and provide them with the possibility to formulate their own opinion.

The report will begin with a broad introduction of the planned project and aim at highlighting the current state of the site, the baseline conditions, the environmental aspects, and current land use. The project development consists of several phases, which will be described in more detail in *Part 2: Environmental Impact Assessment*.

1.2 Project Description

The development of Flemingsbergsdalen is of strategic importance to the Stockholm County regional plan. Currently, the district is dominated by public workplaces; focusing on health care, higher education, research, and justice, including the Karolinska University Hospital, the central office of the southern Stockholm Police, and an educational centre for higher learning. However, the area is largely industrial, and the plan seeks to transform it from an area dominated by industry to a sustainable, innovative, business and educational hub. Currently, over 60 billion Swedish kronor (SEK) will be invested after the approval of the project plan (Huddinge kommun, 2019b).

Unlike the northern municipalities of Stockholm, Flemingsberg and the rest of southern Stockholm do not have active business districts. This has caused an unbalanced flow of goods and people between northern and southern Stockholm (Huddinge kommun, 2019b). It is not sustainable, from an environmental perspective, to only have business districts in the north,

as people have to commute long distances to work. Therefore, developing a new business centre in the south of Stockholm would not only cut down commuting time and emissions from cars, the Municipality also predicts that the new business centre will promote local growth and potentially boost the area's economy (Fabege, 2018a).

In 2018, the Huddinge Municipality board approved the establishment of a plan program for the Flemingsbergsdalen project. The planning permission for the project may be delayed to as late as 2022 (Fabege, 2018a). Construction is proposed to last approximately 10 years after approval, to transform today's Flemingsberg into an urban centre by 2050; thus, making Flemingsberg an important district for education and business, both locally and nationally (RUFS 2050, 2018).

The Flemingsbergsdalen project is divided into six phases with different developmental aspects and purposes that contribute to the area as a whole. As seen below in Figure 1 and Figure 9, there are six phases in the project; 1 - City Centre, 2 - Overlay Development, 3-4 - Residence Area, and 5-6 - Recreational Parks and Schools. The different phases are described more in depth in Part 2, Chapter 2: *Project Phases*.

The project will cover 75 hectares of central Flemingsberg (Lundgren, 2018). Furthermore, the project aims to link the Flemingsbergsdalen area to the rest of Flemingsberg, thus establishing an integrated district. A new overlay spanning from Regulatorbron to Flemingsbron will be created, in order to link the two areas. The overlay is a central part of the project, as the new centre of Flemingsbergsdalen will be located there, as well as a new travel centre (Huddinge kommun, 2019a). Furthermore, the area aims to integrate environmentally friendly design practices, such as green roofs (ibid.).

The proposed vision for Flemingsberg is to develop a centre for 5 000 new residents and 35 000 new workers (Huddinge Kommun, 2019a). With its close proximity to shops, parks, and residential areas, new job opportunities, services, culture, and comfortable living spaces will be created (RUFS 2050, 2018; Huddinge kommun, 2019a). In general, Flemingsbergsdalen will be an area with multi-use spaces enabling people to live, work, and play, all within the same area. By creating spaces like this, Flemingsbergsdalen strives to make it easy to live in the area without a car and encourages other modes of transportation, such as biking or walking. The aim is to create both an active day-time and night-time atmosphere that will make the area feel alive during the day and have "eyes on the streets" at night. In order to create an urban and modern feeling, the area will have apartment buildings and offices with active ground level businesses consisting of stores, cafes, and restaurants. Further integrating the project's multi-use design vision, the project's buildings will serve as sound barriers for central plazas and courtyards (Huddinge kommun, 2019a).

Additionally, the project will contain different types of streets, ranging from smaller pedestrian speed streets, neighbourhood streets, and city streets to large boulevards. This will be done to create a sense of a varied urban environment. Incorporating varying housing heights will also not only create a visually stimulating area, but maximise sunlight (Huddinge kommun, 2019a). This will in turn, create diverse and interesting neighbourhoods which will increase the overall attractiveness of Flemingsbergsdalen.

The primary developers of the project are Huddinge Municipality, who created the plan in conjunction with Fabege and BIG Architects. There have also been consultancy firms involved, such as Tyréns and WSP, that have

made several reports on a variety of predicted impacts from the project. Other agencies and organisations, such as Ekologigruppen, have also been involved with the project.

Currently, there are several businesses, industrial, and residential areas in and surrounding the district that will be affected by the project. As the project progresses, it is crucial that affected parties are invited to participate in the process. As mentioned above, in Section 1.1: Aim of EIA, the Flemingsbergsdalen project is still at an early stage in its life cycle. The consultation phase of the plan program occurred from the 21st of October to the 29th of November 2019, where the public had the opportunity to submit comments through email, visit an open gallery at the Huddinge Municipality Service Centre, and attend an open forum on the 14th of November 2019.

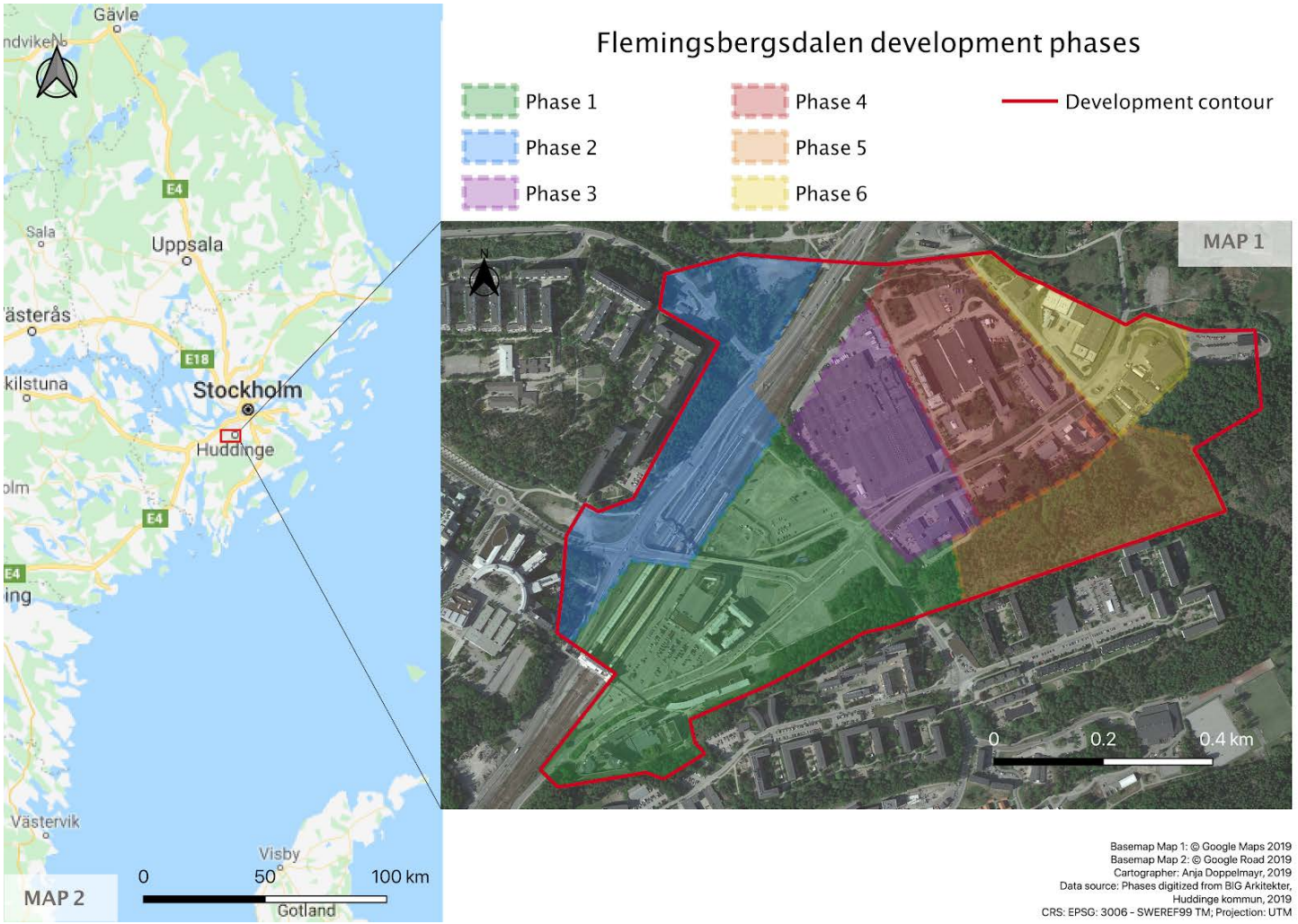


Figure 1. *Development site and construction phases within Flemingsberg, Huddinge kommun south of Stockholm City, Sweden (BIG Arkitekt, Google Maps, Google Road; Illustrated by Doppelmayr, A., 2019).*

1.3 Site Description and Baseline Conditions

This section describes the site and identifies the present and no-project future environmental and socio-economic state of the area, taking into account changes resulting from natural events and human activities, such as population growth, climate change, and related infrastructure adaptations. The selected environmental aspects concern topography and soil, hydrology, biodiversity, and ecosystem services, land-use area and buildings, noise and vibration as well as air pollution. The socio-economic and public health aspects complement the baseline by describing the population, employment, segregation, crime, and radiation. The period for the prediction is set to be comparable to the lifetime of the proposed development (construction, operation). It should be noted that the assumed future development of the concerned area in the last subchapter, does not claim to be fully accurate and exhaustive due to a lack of information, time constraints, and uncertainties in the forecasting process.

1.3.1 Environmental and Natural Aspects

Topography

The site is located in a valley and the surface level area is relatively uneven, varying between 24 metres and 33 metres above sea level. The topography reaches its highest altitude at the southwestern border and lowest at the northeastern border, with a general decrease between the two areas (Tyréns, 2019a).

Soil Features

The valley is mainly covered by loose clay and till. There is an area with loose clay covering the southwestern to the northeastern parts of the district, which is divided by till segments (Figure 2). Within the sections of till, there are smaller areas with up to 2-3 metres of dry sand or silt (Tyréns, 2019a). According to part of the results of geotechnical surveys presented in Tyréns (2019a), the shear strength of the area's undrained clay is 10-30 kPa, with an average value of 20 kPa. The clays in the northeasterly area have a shear strength between 10-20 kPa, with an average value of around 15 kPa. The water content of the southwestern clay varies between 30-45 %, which is lower than the 40-75 % water content of the northeastern clay (ibid.). As the water content in the soil increases, the soil strength decreases (Shi et.al., 2017).

The ground where the project is located is relatively flat, but it has been overlaid by filling soils that were used in previous developments all over the Flemingsbergsdalen area. The filling layer is expected to be thinner in the western area than the eastern. In the northeast, the filling soils were found to be as thick as five metres. In addition, the origin of the filler is unknown (Tyréns, 2019a).

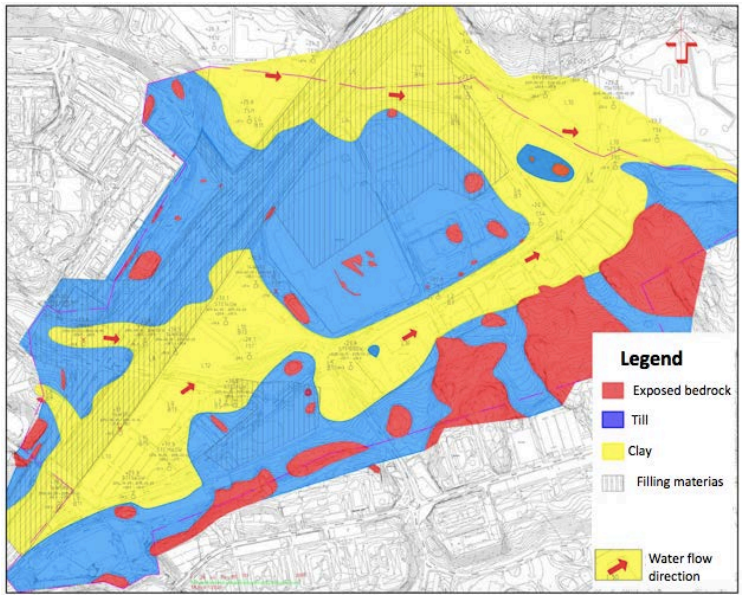


***Figure 2**. Distribution of clays and estimated groundwater flow in the project area on top of a topography basemap. The red arrows indicate the dominating waterflow directions (Tyréns, 2019a).*

Hydrology

The dominating direction of the groundwater flow in the project area is towards the northeast, discharging into Flemingsbergsviken and the Flemingsbergsvikens wetland-complex (Figure 2) (Tyréns, 2019a). The groundwater level is 1-2 metres below the present surface ground level in the soutwestern part and 1.5-3 metres below surface ground level in the northeastern part of the project area. Generally, the areas with higher elevations will have a deeper groundwater level (Structor, 2019). In terms of the absolute groundwater level, the groundwater level in the soutwestern part of the project area is generally higher than in the northeastern part, at 31 metres and 23-24 metres respectively (Tyréns, 2019a). This indicates a groundwater flow direction with a northeastern direction as visualised in Figure 2.

The rainfall visualisation of Flemingsberg (Figure 3), shows large accumulations of water at the area's lowest elevations (Structor, 2019). These areas include three intersections of Kvarnängsvägen: Regulatorvägen, Björnkullavägen and Ebba Bååts Torg, Huddingevägen and Hälsovägen, and the parking area below Regulatorvägen. According to Figure 3, Regulatorvägen acts as a drainage route for surface water. In addition, the water levels in the Flemingsberg basin and the Flemingsbergsviken wetland-complex significantly increase during intense rainfall (Structor, 2019).

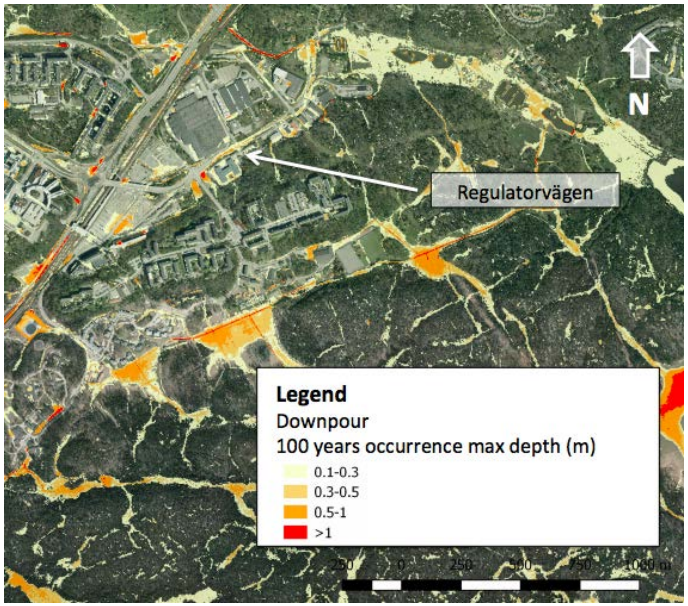


***Figure 3**. Maximum depth of the accumulation of water after rainfalls (Structor, 2019).*

The area consists of two sub-catchments, located in the northern and southern parts of the proposed development areas (Figure 4). Most of the stormwater drains through a system of ditches and pipes from the northern sub-catchment, towards the Flemingsbergsviken wetland-complex and then into Lake Orlången. The lake forms a significant part of the Tyresån Lake system, which spreads over multiple municipalities (including Huddinge). Only a minor part of all stormwater is handled directly via Stockholm Vatten's stormwater tunnel from the southern sub-catchment. In the southern area of Flemingsbergsdalen, the flow direction changes significantly after heavy rainfall. The southern part of the area, will drain on the surface northwards to the northern sub-catchment area rather than southwards as usual (Structor,2019).



Figure 4. *The sub-catchment area Flemingsberg is located in. Surface and groundwater from the developed area in Flemingsbergsdalen (red circle) is transported to the Baltic Sea. The outlet of Orlången catchment is marked with a purple star. (Modified by the authors, Huddinge kommun, 2019a).*

Biodiversity

Biodiversity could be regarded as a regulator of underpinning ecosystem processes, playing a key role in ecosystem service (Mace et al., 2011). The area has clear natural vegetation heights and valleys, belonging to the Södertörn landscape (Huddinge kommun, 2019c).

There are red listed species within Huddinge Municipality. However, since most of the area within the project borders have been exploited, the loss of biodiversity has already occured (Huddinge kommun, 2019j). There might still exist some red listed species within the boundaries of Flemingsbergsdalen, but even with this in mind the natural values within the project area is described as low (ibid.).

Ecosystem Services

Ecosystem goods and services (ESS) provide human beings with various life-sustaining benefits such as clean air and water, fertile soil, pollination, bioenergy, recreation, and flood control. Biodiversity is highly connected to ESS as it regulates the ability of the ecosystem to supply these services (Balvanera et al., 2017). Since the sources for ESS are all forms of living matter, ESS are mainly obtained from the natural and semi-natural areas within, and surrounding, the site of Flemingsbergsdalen. This includes green patches, forests, shrubs, grasslands, and wetland area. Nonetheless, it must be noted that the project site, in contrast to its surroundings, does not provide substantial ESS as most surfaces are sealed and green patches are rare and relatively small in size.

Land Use Areas and Buildings

Land use in the district consists largely of existing business and industrial areas, parking spaces, and hardened surfaces for transport and traffic. Additionally, the close surroundings, which include a residential area, parts of a nature reserve, and cultural sites, that are all taken into account.

Protected Areas

Nature reserves and Natura 2000 areas are valuable natural environments worthy of protection, both from a biodiversity and outdoor life standpoint (Henrikson, 2019). In particular, the nature reserve Flemingsbergsskogen, that overlaps with the southeast part of the project site, bordering Visättra, is of particular importance. It covers a total area of approximately 2 400 acres and is composed of pine forest and wetlands. The reserve is very species-rich and offers ESS for the citizens of Huddinge and Flemingsberg through means of air purification, recreation, urban climate regulation, and the provision of a natural retention space for events such as heavy precipitation and subsequent flood hazards (Huddinge kommun, 2019a).

Commercial Area (Flemingsberg Centrum)

The city centre consists mainly of concrete and asphalt-sealed surfaces for commercial and industrial use. There are no parks within the proposed area and green patches are limited to small fragments between buildings and along roads. However, in the northern part of the area bordering Solgård, open grassy areas, in the form of old arable land, can be found. Small and medium-sized enterprises such as PS Bageri AB, Bil & Motorteknik Per Larsson, Scandinavian Safe AB, are located in the north. While the southern part is dominated by open parking spaces, newly built shopping facilities, such as ICA Maxi and Lidl, and a hotel, Forenom Aparthotel Stockholm Flemingsberg. The northernmost part of the area is used to store forestry products and waste, and the project area west of the rails is mostly unexploited with green spaces along Huddingevägen. Table 1 shows other forms of land use in close proximity to the proposed project site, which are assumed to be affected in the future.

Table 1. *Land use in close proximity to the proposed project site.*

Northwest	Flemingsberg's residential area and Grantorp. They are classified as a site of cultural historical value due to the presence of historical artifacts in the area. This area is specified in Huddinge's cultural environment program (Henrikson, 2019). More information on artifacts is given in Phase 3-4.
Southwest	Educational district with university facilities and a health centre. The academic centre is an important biotechnology site and houses campuses from Karolinska Institutet, the Royal Institute of Technology (KTH), and Södertörn University, with approximately 10 000 students.
Southeast	Visättra quarter with residential areas, a sports centre, and primary and middle schools.
South	Enforcement centre for the southern part of metropolitan Stockholm, with a police station, courthouse, prosecutor's office, and jail.

Transport and Traffic

In general, the city of Flemingsberg is well connected to both the Stockholm region and city through trains, easily accessible by car, and well-served by busses. Thus forming an important traffic junction in the region. Regional trains from Mälardalen and express trains connected to the Arlanda and Skavsta airports stop at Flemingsberg station. The current railway system consists of six tracks with a number of switches south of Flemingsberg station. It also forms part of the Western Main Line (Västra stambanan *sv.*) between Stockholm and Gothenburg. Additionally, there are around 600 car parking spaces are available near the railway and shopping facilities, south of the project area. Both the railway and Huddingevägen run between Årsta, northeast of Flemingsberg, and Vårby, southwest of Flemingsberg separating the proposed project site in the west. As a consequence of the current traffic volume, high levels of noise and air pollution has been recorded (see subchapters *Noise and Vibration*, and *Air pollution* in this chapter).

Natural Values

As shown in Figure 5, the natural value of the proposed project site can be defined as relatively low to negligible. This is due to the fact that no large continuous green spaces with significant biodiversity is located within the area and thus, no substantial ESS is provided. Additionally, the surfaces in the area are widely sealed and used for commercial and industrial purposes, adding sources for air pollution and noise. Therefore, the only areas with a low to moderate nature value are those bordering the nature reserve in the west. Nevertheless, it should be noted that areas of high natural and cultural value are located in the immediate vicinity, therefore impacts on the nature reserve and Grantorp district should be taken into account.

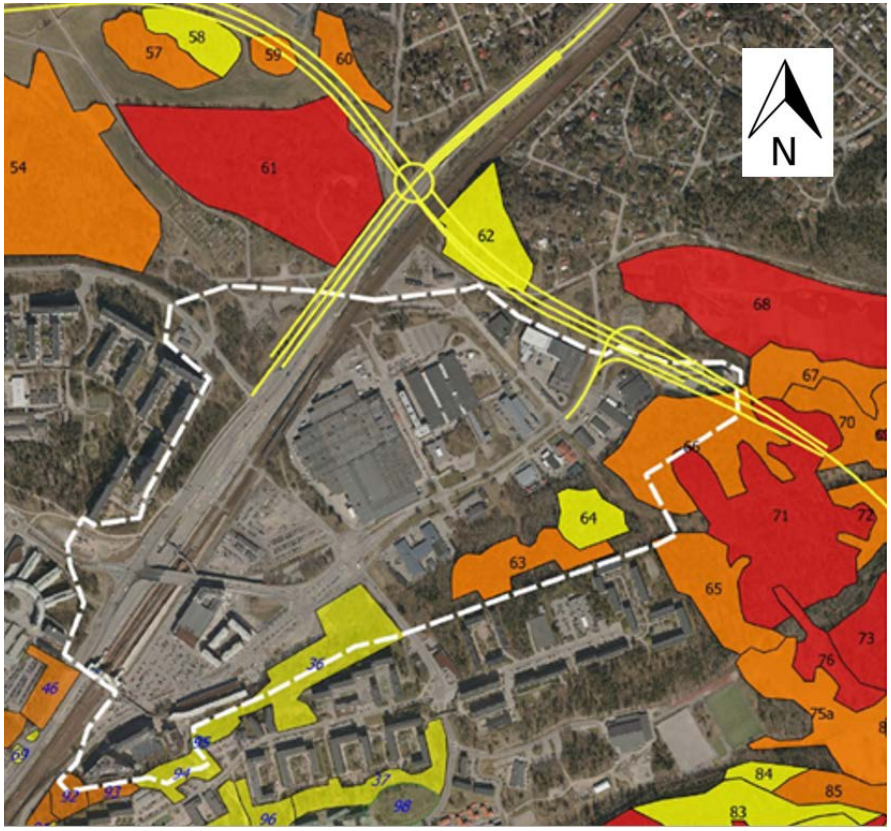


Figure 5. *Nature values within and in close proximity of the proposed project site. Yellow = low (4); orange = moderate (3); red = high (2); dark red = highest (1); blue and white numbers specify the classified area (Henrikson, 2019).*

Noise and Vibration

The main sources of noise and vibration in the area are traffic routes, such as roads and railways within or next to the project site (Engström and Torehammar, 2013). The dominant source of noise from railway operations comes from the vibrations created from the contact between the train's

wheels and rail surface (University of Southampton, 2019). In addition, significant noise is produced daily by car and transport traffic along major roads near Flemingsbergdalen. The level of noise pollution at the given site decreases with a greater distance from roads and railways. Noise levels in 2013 (see Figure 6) ranged from 70 dBA to more than 75 dBA to along train tracks and 40 dBA to 55 dBA in residential, university and hospital areas, and areas bordering the nature reserve. In the commercial and industrial areas, as well as along the roads, noise pollution varies between 55 dBA and 70 dB.

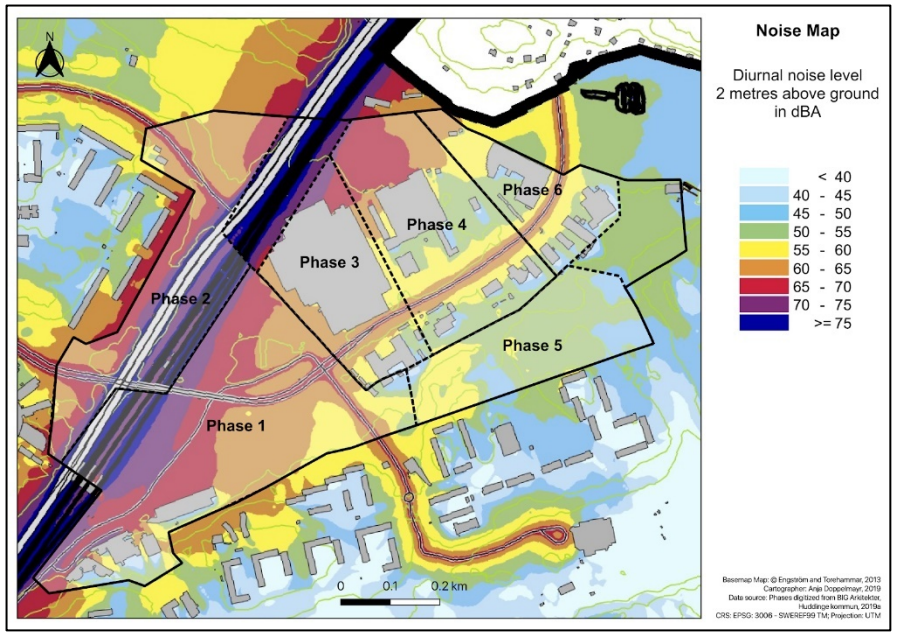


Figure 6. *Noise pollution at the proposed project site in 2013 (BIG Arkitekt; Engström and Torehammar, 2013. Adapted by the authors.).*

Air Pollution

Air pollution maps produced by SLB Analysis on behalf of the Eastern Swedish Air Protection Association (Östra Sveriges Luftvårdsförbund *sv.*) show annual and daily mean values for PM_{10} and NO_2 emissions (SLB analys, 2015.). Both indicators are used to describe the air quality in a given region and should not exceed certain quality standards in order to protect human health. Similar to noise emission, the highest exposure to air pollutants is recorded along the railway lines (Table 2).

Table 2. *Recorded annual and daily concentrations of PM_{10} and NO_2 emissions (ug/m^3) in Flemingsberg in the year 2015. Own representation based on SLB Analys, n.y.*

	ug/m^3	**Quality Standard**
Railway Line		
Annual PM_{10}	15-20	15
Daily PM_{10}	25-35	30
Annual NO_2	15-26	20
Daily NO_2	30-48	60
Other Areas		
Annual PM_{10}	10-15	15

Daily PM_{10}	18-25	30
Annual NO_2	5-10	20
Daily NO_2	18-30	60

1.3.2 Socio-Economic and Public Health Aspects

Population

Currently, there are approximately 15 000 people living in Flemingsberg and 15 000 job opportunities in the area. Around 17 000 students also inhabit Flemingsberg because of the many university campuses located in the area. (Stockholms Läns Landsting et al., 2018). Between year 2018 and 2029, the population in Flemingsberg is expected to increase by 5 731 people (Huddinge kommun, 2019d). In 2018, the working population, consisting of people between the ages of 25 to 64, made up the largest portion of the population, about 9 000 people. The second largest group were those aged 65 and older, which was estimated to be around 1 400 people (Huddinge kommun, 2019e).

Employment

The unemployment rate in the Municipality of Stockholm was 5.9 % in 2019, whereas the unemployment rate in the Municipality of Huddinge was 6.5 %, which is slightly higher than that of the Municipality of Stockholm (Carlgren, 2018). Statistics from the Municipality of Huddinge show that Flemingsberg, with an unemployment rate of 5.1 % in 2019 has the second-highest unemployment rate in the Municipality (Huddinge kommun, 2019e). In 2016 Flemingsberg had a total number of 9 570 workers and 42.8 % has an average annual income between 160 000 - 319 000 SEK, while 40.03 % has an average annual income between 10 000 - 159 900 SEK (Huddinge kommun, 2019e).

Segregation

Segregation has increased in recent years, which has led to socio-economic challenges in many parts of Sweden. Generally, three types of segregation can be identified, socio-economic, ethnic, and demographic segregation. Socio-economic segregation generally refers to spatial separation due to the nature of the job, education, or salary, while ethnic segregation refers to separation due to ethnic, religious, or physical characteristics. Demographic segregation is the result of separation in geographical distribution as a response to age, gender, and type of household (Regeringskansliet, 2016). In a social impact assessment by White Arkitekter, Flemingsberg was identified to have issues with socio-economic segregation and inequalities (White Arkitekter, 2012).

Housing

The national monthly rent for a 70 square metre apartment, equivalent to 3 rooms and kitchen, is 6 615 SEK in Sweden. In Huddinge, the average rent for a 70 square metre apartment is 7 070 SEK per month. Hyresgästföreningen state that the rents are the highest the closer to the inner cities one gets. However, this is not the only factor. Rents are also determined by its construction date. Apartments built in more recent times tend to be more expensive compared to older apartments (Hyresgästföreningen, 2019a).

There are some housing areas in Flemingsberg, generally referred to Miljonprogramsområden, that were built between 1964 and 1975 to address the vast housing shortage (Boverket, 2014). The miljonprogram accommodates apartments with low rent, which constitutes a large proportion of the apartment buildings in Flemingsberg (Hyresgästföreningen, 2019a). Moreover, newly produced rentals are more expensive compared to owned properties (Hyresgästföreningen, 2019b).

Crime

In recent years, the population of Stockholm County has felt less secure in residential areas, squares, parks, and when using public transportation. People often feel insecure in public places during the evening and at night; thus, people choose to forego local activities during those times (Huddinge kommun, Lokalpolisområde Huddinge, Södertörns Brandförsvarsförbund, 2019; Bergman, 2019). Some areas in the Municipality of Huddinge have been identified as being less safe, one of them being Flemingsberg. According to Brottsförebyggande rådet (2019a), from 2014 to 2018, approximately 14 000 - 16 000 crimes were committed in Huddinge Municipality annually. Theories explaining the occurrence of crime have been formulated, such as the theories of defensible space, routine activity, and socioeconomic structure. The theory of defensible space says that by manipulating the physical design of residential areas, residents can take more control of and protect their spaces from crime (Reynald and Effler, 2009). The routine activity theory attributes crime occurring to favourable conditions, in which a motivated criminal and victim are without supervision or protection. The third theory attributes the occurrence of crime to the socio-economic aspects of an area, such as unemployment, lack of education, and poverty (Polismyndigheten, 2005).

Radiation

The ground of the project site has a gamma radiation value ranging from 37-68 Bq/kg (Figure 7), which is about uranium according to SGU's large-scale measurement (Tyréns, 2019a). It could be regarded as a normal ground radon (ibid.). Thus, the radiation is not a negative factor that affects the project's development. But despite this, in order to avoid radiation hazard that is not noticed, further field measurements are also needed to confirm the amount of radiation is at a normal level before construction. As mentioned in the subchapter *Soil Features* in Section 1.3.1: *Environmental and Natural Aspects Soil*, the origin of the soil filler is unknown, which requires particular measurements about radon to guarantee safety before excavation.

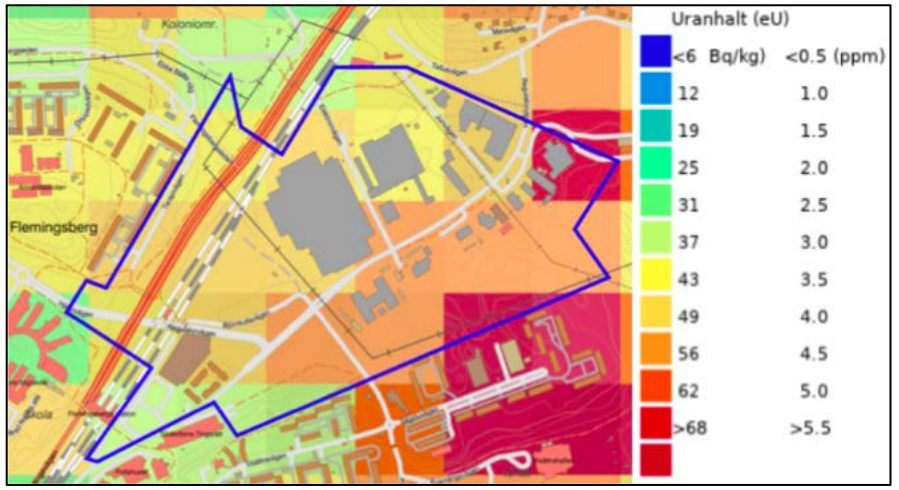


Figure 7. *Gamma radiation from uranium. Plan area is approximately marked with blue (Tyréns, 2019a).*

1.3.3 Future Development

The Stockholm County region currently has about 2.3 million citizens and is expected to grow by 50 %, to 3.4 million by 2050 (RUFS 2050, 2017). Future development will increase pressure on the suburbs of Stockholm and lead to further densification of already exploited areas. The Municipality of Huddinge is expected to increase by approximately 33 000 inhabitants between 2018 and 2030 (SCB, 2018; Huddinge kommun, 2014). Due to the expected population growth, there will also be increased pressure on transport and traffic infrastructure, housing, the labour market, facilities for childcare, business areas, and local industries. From 2006 to 2009, central Flemingsberg has gradually expanded to meet some of these needs; however, as it is assumed to continue to expand in the future, exploitation of new spaces and further densification of already existing areas are necessary.

Such development leads to further issues that need to be addressed, such as future waste management, the resiliency and robustness of roads, and building concepts that counter erosion processes, which may occur due to increased traffic and population density. In 2017, an average of 18 600 cars were travelling along Huddingevägen per day. This is expected to increase to approximately 30 000 cars, on average, per day (Tyréns, 2019b). The demand for trains is also expected to increase to about 400 per day.
In addition to urbanisation, climate change is further pressure that must be considered. This makes it necessary for cities, such as Flemingsberg, to adopt a holistic approach when planning in order to secure a healthier and economically vibrant environment under all circumstances. Climate models run by the Swedish Meteorological and Hydrological Institute (SMHI) show that the mean simulated temperature and mean precipitation in the south of Sweden are likely to increase significantly (Lind and Kjellström, 2008). Overall, the SMHI model shows that the climate is likely to become milder and more humid in the winter, with rising temperatures of nearly 4 °C and an 11 % increase in precipitation (ibid.). As a result, stormwater runoff and flooding events are assumed to become more frequent. Summers in southern Sweden are projected to become drier and hotter, which can lead to greater risks for heat waves in urban areas with long-term consequences on human health (Lind and Kjellström, 2008; Luber and McGeehin, 2008). In *Chapter 5: Climate Change - Risk and Adaptation*, climate change impacts on the project and adaptation strategies are discussed in greater detail.

1.4 Boundaries and Assumptions

Temporal Boundaries

Planning activities on the Flemingsbergsdalen development project began on the 13th of August, 2018. According to the Huddinge Municipality, the temporal boundaries, as stated in the project plan, begin with the initial construction of Flemingsbergsdalen in 2022 (Huddinge kommun, 2019m). The boundaries used in the EIA will encompass the construction of the planned project from approximately present to 2030, with an additional 100 years, when the area is expected to be under operation. While it is possible that the project may operate for a time span of longer than 100 years, a longer timespan is outside of the scope of this impact assessment. Initial approval, to begin further planning, is expected to be granted in 2020. Each of the stages in the development project will be built consecutively, starting with Phase 1. The project development is expected to be completed by 2030 (Stockholm Läns Landsting et al., 2018). Planning of the associated highway (Tvärförbindelse Södertörn), which will pass along the northern boundary of the site, began in 2014 (Trafikverket, 2017a).

Regarding the reversibility and irreversibility of impacts, no time frame was set, as the assessments in *Part 2: Environmental Impact Assessment* consider whether or not it is theoretically possible to reverse an impact.

Spatial Boundaries

There are currently several consecutive projects being planned or in development in Flemingsberg. This EIA focuses solely on the Flemingsbergsdalen project. The southern border of the project reaches 500 metres past the current train station in Flemingsberg. The development is bordered by the neighbourhoods of Visättra and Grantorp, to the east and west, respectively. The northern border begins with Flemingsbergsgård, runs along the Tvärförbindelse Södertörn, and ends with the Flemingsbergsviken wetland-complex (Huddinge kommun, 2019a). The project is also assumed to affect the neighbouring areas of Grantorp and Visättra, and as such, those areas are investigated and included within the spatial boundaries; however, these areas are assumed to not have significant impacts nationally or internationally.

Subject Boundaries

The impacts examined in detail are related to physical components, such as biodiversity, geology, and hydrology. Social and economic components of the development, such as recreation and housing, are considered as well. Due to time constraints, human health aspects of the development are briefly considered; however, a full health impact assessment should be done to obtain the complete range of impacts on human health, if resources allow. When considering the Plus Alternative, the use of different construction materials for infrastructure, construction methods, and location have not been considered. The only location that has been considered is that of the current Flemingsbergsdalen plan.

Process Boundaries

Within the EIA, all parts of the process, according to the European Union (EU) Directive, have been followed, with the exception of consultation with relevant stakeholders and authorities, and public participation, due to time constraints. This EIS was executed in an extremely limited time frame, approximately 6 weeks. Within this time, there was no opportunity available to receive feedback from and consult with relevant actors in the process. The only form of information obtained, from relevant actors, was advice through email communications. In order to gain a better understanding of the scope of the site, several site visits were undertaken. Additionally, the decommissioning phase has not been assessed, as it lies too far into the future to make reliable statements about possible impacts.

Assumptions

The current spatial, temporal, and process boundaries of the area that have been designated in the planning process are assumed to be followed according to plan, arriving at the proposed project completion time of 2030. Due to time constraints, the methodology used is condensed, in comparison to the normal time frame it takes to develop a method over several months. The timing of construction for each of the respective phases are congruent with the project plan.

1.5 Relevant Legislation

The Swedish Environmental Code constitutes the framework legislation needed to govern and manage principles of environmental policy. Its purpose and scope is to promote sustainable and sound development and exploitation; essentially ensuring the protection of human-,

environmental-, and biological health and safety from harmful impacts (SFS 1998:808, chapter 1 §1).

The Environmental Code requires that an EIA shall be submitted due to proposed activity that falls under any of the following chapters (SFS 1998:808, chapter 6 §1):

- Environmentally hazardous activities and health protection (SFS 1998:808, chapter 9 §1 and §4)
- Polluted areas (SFS 1998:808, chapter 11 §1, §2, §3, §4)
- Water operations (SFS 1998:808, chapter 12)
- Or in rules issued pursuant to the Environmental Code

Additionally, in accordance with EC legislation, an EIA must be carried out on the basis of Directive 2011/92/EU (known as 'Environmental Impact Assessment' – EIA Directive), for any suggested plan.

The content of the EIA presented here within follows the legal requirements according to the environmental code (SFS 1998:808, chapter 6 §7).

1.6 Methodology

This section describes the methods that are used to conduct the EIA for this project. The methodological framework was developed to directly address both project-related impacts and cumulative impacts, caused by actions associated with the project, considering other past, present, or future developments that have been or will be carried out.

Overall, this document is a result of the collaborative work of four teams, over a period of six weeks, assessing different phases of the development project, Flemingsbergdalen, in the southern metropolitan region of Stockholm. The work largely focused on identifying, predicting, and evaluating the significance of environmental, cultural, and socio-economic impacts associated with actions during project construction and operation.

To obtain all the information needed for the EIA process and gain a deeper understanding of the project, the Huddinge Municipality Service Centre and district of Flemingsberg were visited on the 27th of November, during which the site was documented with photos. In addition, information was collected through literature research, documentation provided by the community, and written correspondence via e-mail with community representatives and other organisations involved, such as Ida Larsson and Sofia Gregorsson (Plan Architect; Huddinge Municipality), Kristin Lundvall (BioGeo Scientist; Huddinge Municipality) and Birgitta Andersson from the nongovernmental organisation, Naturskyddsföreningen. Due to lack of time it was not possible to conduct personal interviews with residents or representatives of involved organisations.

To ensure that all EIA steps were completed and nothing was overseen in the creation of this report, EU recommendations and international guidelines were followed, and checklists were used (see European Union, 2017; Glasson and Therivel, 2019).

The following subchapters describe the methods used for each step of the impact assessment comprising impact identification, prediction, evaluation, and cumulative impact analysis. It should be noted that not every team used all methods to the same extent and there are some minor variations, particularly in the identification and prediction of impacts.

1.6.1 Impact Identification - Consultation, GIS, Literature Review, and Checklists

To ensure a comprehensive impact identification, various methods such as checklists, literature review, GIS maps, and consultation were used. Expert and public consultation, in particular, are powerful tools in gathering needed information and including personal opinions of citizens affected by the project (Glasson and Therivel, 2019). Although public meetings are seen as an important part of an EIA process, due to resource constraints, no such events were able to be organised. However, the Municipality had an online platform for public comments, concerns, and suggestions, which is now closed, so that future assessments can include this data. The Flemingsbergsdalen project was compared to similar past assessments and case studies to identify potentially harmful impacts on the environment. Furthermore, overlay maps were used, as they aided in understanding the area of interest. Overlay maps provide a visual understanding of the spatial distribution of impacts and areas affected in close proximity to the project location (ibid.). The software used to create such maps were BIG Architects and ProCreate. The input data was obtained from the Municipality planning program for Flemingsbergsdalen (Huddinge kommun, 2019a). All maps presented in the EIS have been produced in GIS or taken from relevant literature. To ensure that no impact is overlooked, simple checklists, as recommended by Glasson and Therivel (2019), were used. The checklists were based on a list of biophysical, social, and economic factors which may be affected by development and thus, proved to be a helpful tool in structuring the identification process (ibid.).

1.6.2 Impact Prediction and Evaluation - Impact Matrix

The objective of impact prediction is to identify the magnitude of environmental changes and the sensitivity of the environmental receptor to those changes (Glasson and Therivel, 2019). To determine these dimensions, the changes in the environment with the project are compared to the baseline, which is the situation without the given development (ibid.). The information necessary for the determination of magnitude and sensitivity was obtained through scientific research papers and supported by a comparison to the Swedish Environmental Quality Standards and other similar projects. The results provided the basis for the evaluation of significance by combining magnitude and sensitivity.

To visualise, summarise, and determine the significance of key impacts of the project during the construction and operation phase, each group used the same impact matrix, as shown in Table 5. The x-axis provides an overview of specific actions during the construction and operation phase, which may cause potentially harmful impacts on the natural, cultural, and socio-economic environment. The y-axis of the matrix shows the environmental indicators, which are impacted by different actions and give an indication of how the environment will respond to changes. Table 4 shows each indicator and provides definitions of such indicators. The identified and predicted impacts can be classified according to their significance. In total, five levels of impact significance, from major beneficial in dark green to major adverse in dark red, as well as negligible in white, have been used for the matrices (see Table 3). To enable individuals with colour blindness to read the results, corresponding symbols are used in addition to the colours. In order to ensure an equal understanding of the classifications and minimise the risk of uncertainties due to subjectivity, each grading type was defined before assessments were made.

It should be noted that the matrix presented was only used for the evaluation of the planned project and Plus Alternative. The Zero Alternative has been evaluated in-text only and no matrix is used. This is mainly due to the circumstance that all actions, within the construction and operation phases, were not applicable when assessing the Zero Alternative.

For the determination of the overall project impacts and to summarise such impacts, the phase-based matrices were merged by discussing each impact in a group comprising representatives of each of the individual phases. Through the discussion process, a common consensus was found and the impacts across all phases were determined. For discussion, no specific method was used.

Table 3. *Significance scale and definitions. Based on own representation.*

Major adverse	- -	The receptor has no capacity to absorb change and adapt ***and/or*** the risk/probability of fully losing resources/habitats is high ***and/or*** negative long-term impacts exist ***and/or*** impact is not reversible and mitigable ***and/or*** impact affects the regional scale ***and/or*** impact is of high magnitude.
Minor adverse	-	The receptor has a moderate capacity to absorb change without altering its present character ***and/or*** negative short-term impacts exist ***and/or*** impact is reversible and mitigable ***and/or*** impact affects the local scale ***and/or*** impact is of small magnitude.
Negligible	0	Almost no change in comparison to the baseline, due to very low impact magnitude and receptor sensitivity ***or*** the actions within construction and operation are not applicable to the indicators and project phase.
Minor beneficial	+	Minor additional and beneficial effect(s) or feature(s) on the local area/community ***and/or*** positive short-term impacts exist ***and/or*** impact affects the local scale ***and/or*** impact is of small magnitude.
Major beneficial	+ +	Major additional and beneficial effect(s) or feature(s) on the local area/community ***and/or*** positive long-term impacts exist ***and/or*** impact affects the regional scale ***and/or*** impact is of high magnitude.

Table 4. *Definitions of indicators for impact prediction and evaluation. Based on own representation.*

Indicators	**Definitions**
Biodiversity	The variety of living organisms on earth. Flora, fauna, bacteria, and fungi (National Geographic, n.y).
Air (Quality)	The air needs to be of good quality to not affect humans, animals, vegetation, and cultural values. Air pollution can be caused by factors such as traffic and industrial activities (Svenska Luftvårdsföreningen, n.y.).
Surface Water	Flux of rain water, as well as melted snow and ice. Water that flows over open surfaces (PBL Kunskapsbanken, 2015a).

Groundwater	Cavities in the soil or bedrock filled with water. Includes the quality of groundwater, infiltration processes, and contamination (NE Nationalencyklopedin AB, n.y; Britannica, n.y.).
Noise	Noise occurs from traffic, industrial activities, and construction activities (PBL Kunskapsbanken, 2015b).
Soil	The soil and its quality are mainly affected by contamination and compaction from constructional activities, such as the use of heavy machinery (Cocârta et al., 2017).
Cultural Heritage	Cultural heritage or values can be buildings, or objects, that have cultural-historical values in the area of interest (Statens Fastighetsverk, 2016).
Visual Landscape	The visual landscape character is the result of natural and anthropogenic impacts. It can be what people see outside their window, but also the land use in the area. It is defined here as the aesthetic value of the landscape (Swedish National Heritage Board, n.y.).
Housing	"Housing is a material object, a good that can be manufactured and demolished, produced and consumed, perceived and experienced, bought and sold." (Ruonavaara, 2017). In this regard, housing refers to the material, the hard substance of a building. "At the same time 'housing' can refer to people getting 'housed', that is, getting access to housing". Thus, "housing" refers to both "(...) the actions of social actors and the material products of these actions" (ibid.). In a broader sense, the definition used in this EIA includes the type, layout, location, and physical aspects of buildings, as well as social aspects regarding affordability and attractiveness.
Recreation	Diversity and quality of leisure activities, such as the use of museums, cinemas, green spaces, and parks. Having a vast array of recreation available in an area is beneficial for public health. Recreation can be viewed as personal experience (what it does to a person), as activities (the forms it takes) or as an institution (the structure in which it is made available to the community). Recreation can also be viewed as a process (what happens to an individual) and as a structure (the framework in which recreation is practised). (Torkildsen, G., 1986).
Health	Health is a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity (WHO, 1948).
Safety	Safety is a state in which hazards and conditions leading to physical, psychological, or material harm are controlled in order to preserve the health and well-being of individuals and the community. It is an essential resource for everyday life that an individual and a community need in order to realise their aspirations. (Centre collaborateur OMS du Québec pour la promotion de la sécurité et la prévention des traumatismes et al., 2000)
Equality	"Equality is about ensuring that every individual has an equal opportunity to make the most of their lives and talents" (Equality and Human Rights Commission, 2018). Under this consideration, aspects regarding the concepts of "segregation", "gentrification", "displacement", "disparity," and, in a wider perspective, "accessibility" to the housing and employment

	market for disadvantaged people are incorporated.
Employment	Employment is linked to the creation of jobs, where aspects such as equal access to the labour market, number of jobs, and their short- and long-term availability are included. Moreover, employment relates to the availability of commercial areas and the companies' and enterprises' access to a skilled workforce.
Accessibility and Connectivity	Accessibility is understood as both the possibility to easily reach a location, which refers to the travel time required to get from point A to B, and access to public facilities, services, parks, and leisure areas. In this sense, accessibility addresses strategies of mobility, through the means of traffic and transport, availability to all social groups, and accessibility to public services and recreation (Handy, 2002). Connectivity refers to the connection of different regions, city quarters (ie. through the overlay development), and social groups, by offering facilities for sport activities or meeting points in parks/churches, for example.

Table 5. *Used Impact Matrix with examples for the significance of impacts. Based on own representation.*

		Construction Phase		Operation Phase		
	Actions / Environmental Indicators	Action a	Action b	Action c	Action d	Action e
Natural	Indicator 1	+ + - -		+ +	-	
Natural	Indicator 2		+ +			- -
Cultural	Indicator 3					+ +
Cultural	Indicator 4	+	- -			+
Socio-Economic	Indicator 5			-	+	
Socio-Economic	Indicator 6		+			+ -
Socio-Economic	Indicator 7	+ +		+ +		
Socio-Economic	Indicator 8		- -	+		-

1.6.3 Cumulative Impact Analysis - Causal Loop Diagram (CLD)

The cumulative impact analysis in this report is based on the methodology of system dynamics. In such a system, casualties and links between relevant variables are examined in order to understand the overall behaviour of the system under changing circumstances (The Systems Thinker, 2011). Through the analysis of the overall system, cumulative impacts can be identified and mitigated in order to provide the environment with a more desirable outcome. Therefore, a CLD is a useful way to visually represent

how different variables in a system are interconnected and influence each other.

A CLD consists of a set of variables and connecting arrows, which indicate the direction of the causal relationship between the stated variables. A positively (+) marked arrow means change occurs in the same direction; if one variable increases or decreases, the other behaves in the same manner. A negative (-) link means that change occurs in opposite directions; if one variable decreases, the other increases, or vice versa (see Figure 8). Upon examination of the casualties in the system, feedback is revealed (The Systems Thinker, 2011). As described in the guidelines for drawing CLDs, feedbacks regulate the dynamic behaviour through reinforcing loops, that drive the system, and balancing loops, that slow it down (ibid.). To identify the loop type, the link direction and its positive and/or negative character must be taken into account.

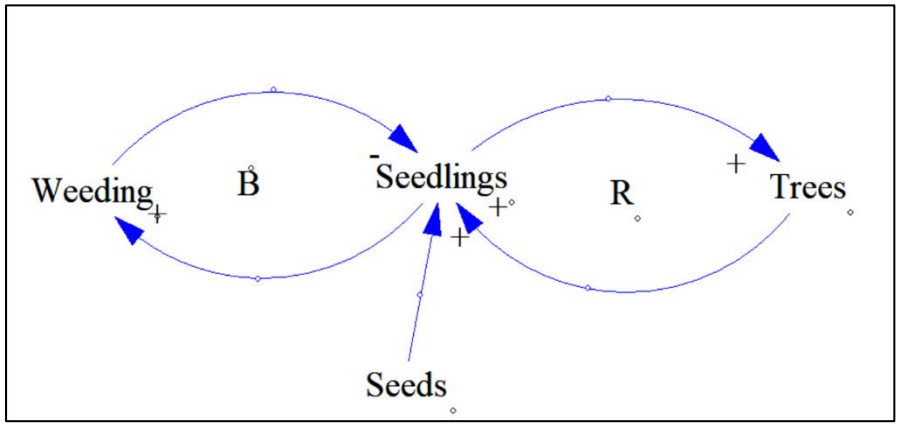


Figure 8. *Example of a Causal Loop Diagram for the regulation of seedling growth. Based on own representation.*

CLDs are a qualitative method; therefore, no conclusions can be drawn about the magnitude of the impacts, environmental sensitivity, or significance of compounds. To find answers to these questions, a numerical computer model based on the CLD, would have to be created. However, due to a lack of quantitative data, at the current stage of the project, and time constraints, a computer model was not able to be prepared for this EIA.

1.7 Uncertainties

It is important to note that all impact assessments performed in this report are based partially on assumptions. Despite several surveys on the geological and hydrological properties of the surroundings, no in-depth analysis or calculations yet exist on how the project will stand in relation to the physical conditions in the project area. Thus, the assessment has been based on limited amounts of data. Additionally, the effect of the impact may not hold depending on the course of action taken by the developers (e.g. if the developer chooses to minimize or extend the scale of the project, or if the design of the project would alter), or when taking into account the development of future projects.

Some of the future projects (Tvärförbindelsen and Spårväg Syd) are mentioned and briefly assessed in Chapter 5: *Cumulative Effects*. However, a full EIA of these projects does not exist, nor is it included in the scope of this assessment, which could essentially lead to the underestimation of presented impacts.

Additional uncertainties also lie in the estimation of impacts due to climate change in relation to the future status of the new centre, as the models

used often simplify these systems. Also, the inherent flaws in the methods used for some surveys, i.e. the inventory of species, add to the uncertainties.

All uncertainties mentioned above might also affect which impacts are presented in this report; if the data which lay as basis for the inclusion turns out to be false, there might be several impacts that are falsely included or excluded in the EIS; impacts are only described in the text if they are determined to have a beneficial or adverse impact. All other actions which are assessed as having little to no impact are deemed negligible in terms of significance.

1.8 Description of Alternatives

This impact assessment is based on the Flemingsbergsdalen project plan described in Flemingsbergsdalen Plan Programme (KS-2018/1281.313) (Huddinge Municipality 2019a). Other feasible alternatives have been considered in this EIA to ensure that the size and design of the project is considered, before proceeding with the project. In addition to the project plan, two other alternatives are considered in this EIA, the Zero Alternative and Plus Alternative. The Zero Alternative is referring to a hypothetical scenario where the planned project will not be undertaken. The impacts from a “no-action” alternative is assessed. The Plus Alternative provides some new suggestions of improvements to the proposed development. This Plus Alternative suggests a smaller project area, alternative design options and various mitigation solutions.

Part 2: Environmental Impact Assessment



The second part of this report consists of the identification, prediction and evaluation of environmental impacts. Each of the four phases are described according to their description, baseline and phase-specific boundaries. Following this, the impact assessment of the planned project is presented based on the identified environmental-, socio-economic-, and cultural aspects for each phase, respectively. Two project alternatives are then presented, the plus and zero alternatives. The Plus Alternative is based on the project being carried out with the best available technology and using the best ecological and environmentally sustainable practices. The zero alternative, on the other hand, is the result of not carrying out the proposed project at all. Finally, a summary of the impacts is presented along with proposed mitigation measures.

2. Project Phases

The six different phases are described in this chapter and the spatial extent of the different phases can be seen in Figure 9.



Figure 9. *The six different project phases presented in the project plan (Huddinge kommun, 2019a).*

2.1 Phase 1: City Centre

In this chapter, the environmental impacts associated with the development and operation of a new city centre in Flemingsberg are assessed. This development includes a wide range of culture and leisure hubs, entertainment, commerce, public service, sports, residential and social services (Figure 10 and Figure 11).

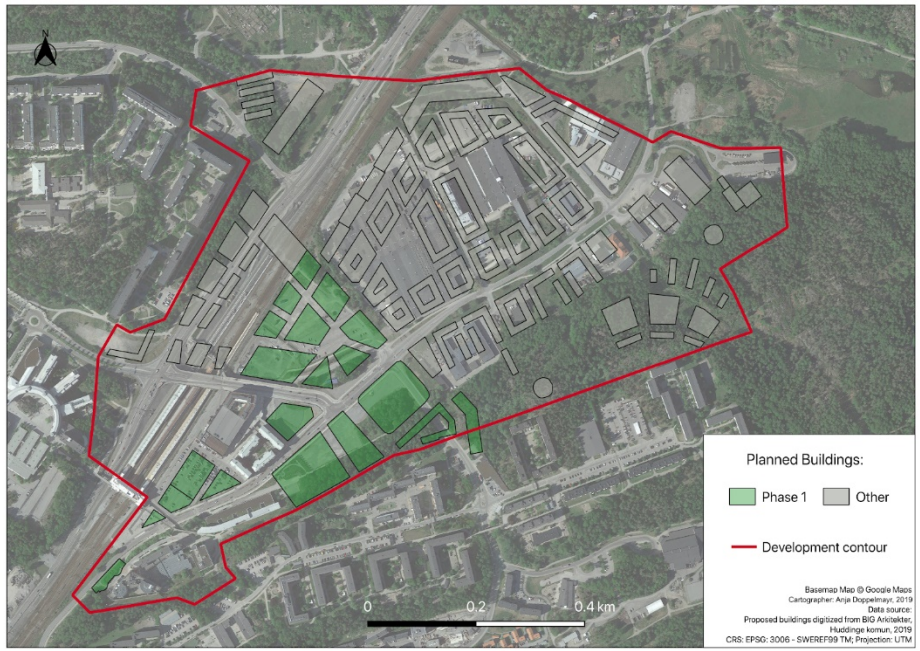


Figure 10. *Spatial boundaries for the proposed Flemingsbergsdalen project and planned buildings for the proposed Flemingsberg city centre - Phase 1 of the development (BIG Arkitekt, Google Maps. Illustrated by Anja Doppelmayr, 2019).*



Figure 11. *A 3D vision image of the proposed Flemingsberg city centre - Phase 1 development (Huddinge kommun, 2019a).*

2.1.1 Phase Description

This phase of the development is in agreement with the Flemingsberg development objectives for 2050 and it seeks to address objectives 1, 2, 4 and 5. As per the Flemingsberg Planprogram, the development objectives are as follows:

Objective 1: Living city centre - urban and diverse city centre with unique identity.

Objective 2: Obvious choice of establishment in an attractive location for knowledge intensive business and creative industries.

Objective 3: Open university city, living and multi-science campus with diverse higher education and world-class research.

Objective 4: Desirable living environment with proximity to city life, culture and nature.

Objective 5: Sustainable society - long-term sustainable development with man at the centre.

Phase 1 of the project will be the heart of the city centre and will be established 500-700 metres from the new travel centre, which will include commuter trains, long distance trains, busses and trams making it possible to live and travel to and from Flemingsberg without the need of a motor vehicle.

Development in Phase 1 aims to completely change the landscape and land use of the area from a large scale business area to a green and sustainable city consisting of mixed developments with a high density of modern, green buildings and associated infrastructure (Figure 11) (Stockholms Läns Landsting et al., 2018; Huddinge kommun, 2019a). According to Huddinge kommun (2019a), the existing businesses in the area will be gradually replaced with green modern buildings, but will most likely remain alongside the new infrastructure for the duration of the development.

These developments will increase the influx of new businesses, create ample job opportunities for local residents, increase the quality of public services and infrastructure, and establish several cultural and leisure centres that will attract visitors and encourage residents to engage in social activities in order to enjoy a better quality of life (Henrikson, 2019).

Currently Flemingsberg is already an active centre with higher education and research institutions, law enforcement centre and shopping centre, Flemingshallen, located there, however, the area is mostly active during day-time, but still lacks a lively, urban feel. To address this and attract more people to the area, the development of Phase 1 aims to further bring the town to life during night-time as well, and this will be done through the development of events and entertainment centres, a sports centre and other culture and leisure centres (Stockholms Läns Landsting et al., 2018). The vision is to have a lively city every hour of the day and be able to deliver urban qualities close to residents, such as new workplaces, public transport and other public areas where people can meet for social events (Henrikson, 2019). The cultural and events centre, currently of unknown size, that will be developed in this phase will make the city attractive enough to host international events that will place Flemingsberg on the map at regional, national and international levels when it comes to social and entertainment activities. The entrance to the event centre will be located at the junction of Regulatorvägen and Kvarnängsvägen to make it accessible.

2.1.2 Baseline

The built environment of Phase 1 of the project which will be Flemingsberg downtown is situated at the southern part of the Flemingsbergsdalen project area. Flemingsberg Centrum comprises of newly built shopping facilities with big supermarkets, newly built apartments, a hotel, two large

open vehicle parking lots and a cultural and leisure centre including an indoor sport and training facility and a library envisaged to start operating in spring 2020. Located along the south eastern boundary is a well established law enforcement centre characterised by the prosecutor's office, the district court and a police department with custody or detention centre. On the eastern boundary of the project area, in the Visättra area, there are residential apartments and schools located in close proximity to the project boundary. The area north of the phase boundary, is an industrial area and has been classified as Phase 3-4 of the Flemingsbergsdalen development. Higher education and research institutions such as the Karolinska Institute Campus Flemingsberg and Södertörn University are located in the surrounding area along the western boundary. Refer to Figure 12 and Figure 13 showing the current built infrastructure.

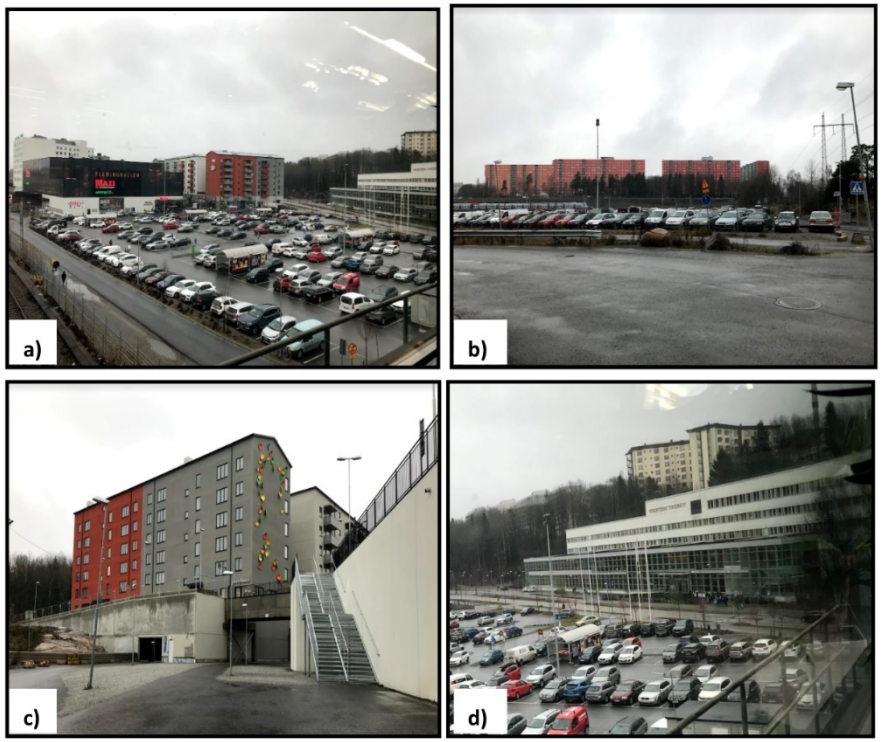


Figure 12. *a) Flemingsberg Centrum with cultural and leisure centre (Fleminghallen), shopping facilities and parking lots. b) Vehicle parking lots behind Flemingsberg Centrum, north of the Regulatorbron. c) Newly built apartments adjacent to the Centrum. d) Södertörns District Court with the prosecutor's office.*



Figure 13. *a) Pedestrian bridge from the train station, over the parking lot and Björnkullavägen, leading towards the law enforcement centre (Södertörns District Court and police department). b) and c) Paved areas within Phase 1. d) Undeveloped open area beyond the parking lots situated north of the Regulatorbron.*

Along the western boundary of the project area there is a railway line and Flemingsberg train station, parallel to Huddingevägen which is used for transportation of dangerous goods. The Regulatorbron is located behind the centrum (Figure 14). There is also some construction or maintenance currently underway on Regulatorbron.



Figure 14. *Regulatorbron behind the Centrum (left) and Flemingsberg train station (right).*

Within the vegetation and biodiversity of Phase 1, there are mainly two fragmented forest patches (Figure 15). One smaller forest patch is located along the Ebba Bååts torg, north of the Regulatorvägen, adjacent to the undeveloped land. Along the south eastern phase boundary bordering the Visättra area ranging from Kvarnängsvägen to Södertörn District Court, the terrain has been described as hilly and consists of a larger patch of coniferous forest and small patches of deciduous forest adjacent to the district court. The assigned natural and biodiversity value for this area is 4 and has been classified as low (Henrikson, 2019). The north eastern boundary of Phase 1 constitutes a forest with a nature value of 3 which is significant, however this falls outside of Phase 1 boundary.



Figure 15. *Patches of forested areas within the phase. The hilly terrain bordering the Visättra area (left) and the forest patch between Björnkullavägen and Ebba Bååts Torg (right).*

Prior to 1975, the land use and soil for Phase 1 where Flemingsberg Centrum is currently located used to be agriculture. During this period, the ground was filled with unknown materials and, when the soils were sampled in the area, the results revealed elevated levels of polyaromatic hydrocarbons (PAH), heavy metals, calcium chloride, sodium dichromate, oils and petroleum hydrocarbons, mostly found nearby industry buildings. The soil profile for this area comprises of top soil, clay, till or bedrock. The valley consists of a deep layer of clay and the shear strength is assessed to be low to very low (ca. 20 kPa), additional filling over the already existing could result in the ground becoming more unstable. The hillside towards Visättra is made out of bedrock and till. The most recently geotechnical feasibility study indicates that this area has firmly fixed bedrock and therefore has low risk for large-scale landslides. (Tyréns, 2019a; Tyréns, 2019c; Henrikson, 2019).

The main source of noise in Phase 1 comes from Huddingevägen and commuter and regional trains railway. The daily average for vehicles that use Huddingevägen is approximately 30 000. The level of noise in the area is 55-60 dBA at a distance of about 250 metres east of the road and railway, while being around 65-75 dBA right by the rails and road (Tyréns, 2019b). According to guidance and benchmark values for noise levels emitted from existing roads and railways provided by the Swedish Environmental Protection Agency (Naturvårdsverket, 2019a), these levels are above the acceptable noise levels in the vicinity of homes. There's also some noise from helicopters flying to and from Karolinska Huddinge Hospital, which is located 800 m away from Phase 1. The daily average vehicle traffic in the vicinity of Phase 1, mostly on Huddingevägen, is expected to increase up to 40 000 by the year 2045 (Tyréns, 2019d). With the development of Flemingsbergsdalen, the expected increase in traffic from Huddingevägen, railway and surrounding roads, will probably increase the existing noise levels.

The main contributors to air pollution around the project area are Huddingevägen and the railway, for both the commuter and regional trains, which pass through Flemingsberg station, part of which is located within Phase 1. The area's air quality was assessed by SLB analysis on behalf of the Eastern Swedish Air Transport Association in 2015 and consists of measurements of the daily mean levels of particulate matter 10 micrometres or less in diameter (PM_{10}) and nitrogen dioxide (NO_2). High levels of 25-30 µg/m^3 of PM_{10} were measured along Huddingevägen, the railway and along Kvarnängsvägen (Appendix 1A) (SLB analysis, 2015), which are all located within and around the spatial boundaries of the phase. The threshold for PM_{10} levels according to the National Environmental Quality Objective of Clean Air is 30 µg/m^3 and the threshold for the Environmental Quality Standard is 50 µg/m^3 (Svensk Författningssamling

SFS 2010:477; Naturvårdsverket, 2019b). The average levels of PM_{10} are between 20-25 µg/m^3 in Phase 1. Based on these guidelines, PM_{10} emitted around the study area does not exceed the Objective or Quality Standard limits. The levels of NO_2 range from 18-36 µg/m^3, with levels nearest to Huddingevägen. The highest levels were measured along Huddingevägen and the railway, at around 36-48 µg/m^3 (Appendix 1B) (SLB analysis, 2015). This is below the threshold of 60 µg/m^3 for NO_2 according to the Environmental Quality Standards (Svensk Författningssamling SFS 2010: 477) and there are no environmental objectives defined regarding the daily mean level of NO_2 (Naturvårdsverket, 2019b).

The development of the area will increase both the number of people and the density of the population. Resulting in an increase of traffic both on the road and the railway, this will most certainly affect the levels of PM_{10} and NO_2 and mitigation measures should therefore be considered.

2.1.3 Boundaries

The Phase 1 area is approximately 22 hectares (Figure 10). The impacts of this development are not only limited to the local area of Flemingsberg but could extend to the region surrounding the project area in Huddinge Municipality. Some impacts, such as those contributing to climate change, could extend to the international scale, however, these will not be assessed in detail for the scope of this project. Their importance is recognized and must be assessed thoroughly by experts in the form of other studies. Stockholm County has housing challenges, especially with the significant population growth and the influx of international students each year, therefore, impacts associated with housing will be assessed and evaluated within both local and regional boundaries. The subject and process boundaries are the same as the entire project, and as such, are not discussed in this section.

2.2 Phase 2: Overlay

2.2.1 Phase Description

Development in Phase 2 aims to further connect the surrounding areas of Flemingsberg to each other and the rest of Sweden. This will be achieved through means of an overlay above the train station and expansion of public transportation in the area, so that Flemingsberg station can operate as a major transport node in southern Stockholm (Huddinge kommun, 2019a). In addition to this, Phase 2 will also include the lowering of Huddingevägen and new building development, both on the overlay and the area west of the overlay (see Figure 1 and Figure 16).

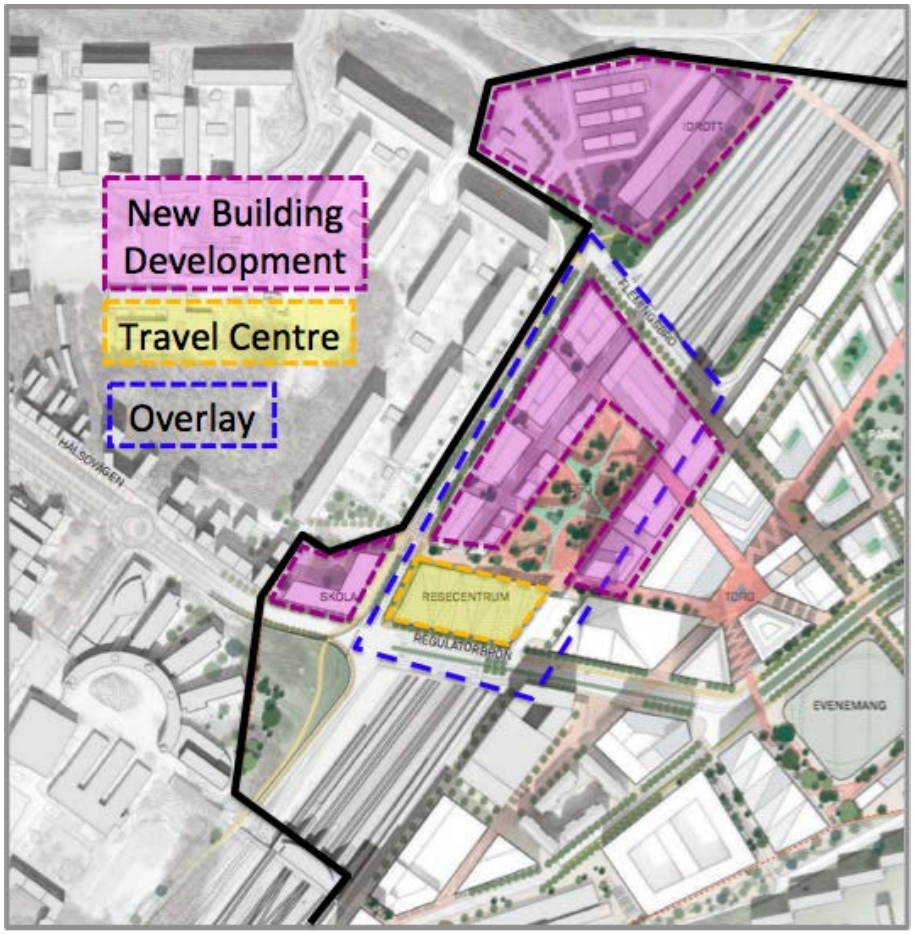


Figure 16. *Illustration plan of the proposed overlay (blue), travel centre (yellow), and new building development (purple) in Phase 2 (Huddinge kommun, 2019a; Modified by the authors). The black border illustrates the area that is included in the planned project.*

The main purpose of the overlay is to reduce the barrier effect of Huddingevägen on Flemingsberg (Huddinge kommun, 2019a). At present, the road separates the proposed new Flemingsbergsdalen area, known as Visättra, from the university campus and Grantorp residential area (see Figure 17). By connecting the east and west Flemingsberg areas, the overlay will facilitate business operations and transportation links in Flemingsberg. The Municipality's vision for Flemingsberg is for it to be a relatively car-free district; therefore, commercial traffic will be moved to the outskirts of town, so that local streets can be of more use to pedestrians, bicycles, and public transportation (Huddinge kommun, 2019a). Regulatorbron will strictly be for pedestrian, bicycle, and public transportation use, while Regulatorvägen will act as the major link between the two sides for both car and bus traffic

(Huddi nge kommun, 2019a). With an increase in public transportation, residents and working people in the area will ideally have to travel a maximum of 400 metres in order to access a public transportation stop (Huddinge kommun, 2019a). This, in turn, will allow for more sustainable methods of travel in the area, as transport in Flemingsberg is presently dominated by cars.

The overlay is expected to be approximately 380 metres long, including the bridges, 70 metres wide, and cover an area of around 44 000 m^2 (Huddinge kommun, 2019a; Kallrén, 2019). While the northern end of the platforms is to be covered, two-thirds of the station will still remain open, in terms of length (Huddinge kommun, 2019a). The overlay is expected to cover the entire track area, in terms of width, including the 6 existing tracks and 2 new proposed tracks on either side of the existing tracks (Huddinge kommun, 2019a). The overlay will be separated into two sections, one for road traffic and one for railway traffic. The section for railway traffic will consist of 2 tubes, approximately 30 metres wide, constructed with 3 lanes in each tube, with the ability to expand on each side to account for the 2 newly proposed tracks (Kallrén, 2019).



Figure 17. *Current layout of Flemingsberg, with the train track area and Huddingevägen separating the two sides of Flemingsberg. Picture taken by Nicole Jang, from the train station along Regulatorbron, during the site visit to Flemingsberg on November 27th, 2019.*

While the overlay will help to facilitate connections within the Flemingsberg area, the project also aims to connect Flemingsberg to the rest of Sweden, in particular, the Stockholm County area. The vision is for Flemingsberg to be, "...an attractive and efficient exchange point for busses, trams, bicycles, and trains" (Huddinge kommun, 2019a). Unlike the north,

the south of Stockholm currently does not possess a major traffic node (Fabege, 2018b). Therefore, the project aims to make the area more accessible by public transportation through the extension of the train station and possible extension of the tramway, Spårväg Syd. The project will extend platforms north of the commuter trains and construct a possible third entrance to increase the capacity of Flemingsberg station. The expansion will allow for more accessibility, as the station is expected to experience an increase in both local and regional train traffic. Additionally, the Swedish Transport Administration (Trafikverket) has already designated a reserve for 2 new railway tracks, on either side of the existing tracks, to account for this future increase and the ability for high-speed rail (Huddinge kommun, 2019a). The project also looks into further extension of the new tramway, Spårväg Syd, between Flemingsberg and Älvsjö. Spårväg Syd is currently planned to have its terminus station at Regulatorbron, however, the proposed extension would bring it further along Regulatorvägen, down into Flemingsbergsdalen, thus covering the northern parts of the district (Huddinge kommun, 2019a).

To account for the expansion of transportation in the area, Huddingevägen must be lowered, moved west, and covered from Regulatorbron to slightly east of Flemingsbergsleden (Huddinge kommun, 2019a). The cover over the road is approximated to be 420 metres long, including the connecting bridges (Huddinge kommun, 2019a). Road covers are considered tunnels if they exceed 100 metres in length, therefore this covered area will be considered a tunnel and be subject to specific legislative guidelines (Huddinge kommun, 2019a). This covered area is also included in the overlay. As mentioned above, the overlay consists of two sections, one of which is designated for road traffic. The road traffic section will consist of 2 tubes, around 10.5 metres wide, with 2 lanes in each direction (Kallrén, 2019). Currently, Huddingevägen resides beside the train station and has a slight incline, so that road traffic does not operate at the same height as train traffic (see Figure 1). Therefore, Huddingevägen will be moved west, to make way for an additional train track, and lowered, so that it operates at the same level as train traffic, therefore allowing it to be covered by the overlay. Ramps with slipways and exits will also be built between Huddingevägen and a newly planned interchange, called Solgård. Solgård will provide Flemingsberg with more traffic, while also displacing it outside of the city centre area (Kallrén, 2019). Because of the short distance between Solgård and the overlay, the inclination of the ramps will be steep.



Figure 18. *Current state of Huddingevägen, including location beside the train track and slight incline. Picture taken by Nicole Jang, from the train station near Karolinska University Hospital, during the site visit to Flemingsberg on November 27th, 2019.*

The expansion of public transportation and construction of the overlay will also allow for an influx of people to the area, thus creating a more lively atmosphere during the day and evening (Fabege, 2018b). A large amount of buildings will be constructed in the area in order to optimize building opportunities and create meeting places for people. Among the new building development in Phase 2 is a secondary school, proposed to be built in the southwest corner of the project area near the Karolinska University Hospital (see Figure 19). Although it is unclear whether or not they will do so, the overlay also gives room for higher education institutions to expand in the area, as denoted by the red area in Figure 19. In addition to development near the university campus, a new sports centre will be built in the northwest corner of the district, which at present, is a forested and uninhabited area (see Figure 19). Behind the sports centre, 4 new apartment buildings will also be built (see Figure 19). On top of the overlay, development will include a main square, a travel centre, office buildings and apartments (see Figure 19). The square will be centrally located and include greenery, seating, art, and lighting (Huddinge kommun, 2019a). A travel centre will also be built close to Regulatorbron, enclosing the main square on one side. The other sides of the square will be surrounded by a combination of office and apartment buildings. On the ground level of these buildings, outdoor restaurants and shops have been proposed in order to increase the number of people in the area and make the main square a lively and convenient meeting place (Huddinge kommun, 2019a).



Figure 19. *Proposed building development and uses in Phase 2 of the planned project (Huddinge kommun, 2019a. Adapted by the authors).*

While the developments in Phase 2 are likely to bring more people and transportation linkages to the area, it is important to note that Phase 2 is strictly dependent on the priorities, planning, and investments of state and regional authorities (Huddinge kommun, 2019a). Additionally, the project is still in its planning and consultation phase at this point in time, so it is unclear whether all highlighted proposals will be approved and developed.

2.2.2 Baseline

The area in Phase 2 consists mostly of hardened areas, such as roads and railways; therefore, there is no nature value within the phase's area (see Figure 5) (Henriksson, 2019). At present, both the road and the railway make up a barrier that divides Flemingsberg into two parts. The only existing connecting passages are Regulatorbron, a bridge for cars over Huddingevägen, and a smaller bridge at the south end of Flemingsberg station, for bicycles and pedestrians. Huddingevägen stretches between Årsta, northeast of Flemingsberg, and Vårby, southwest of Flemingsberg, with two lanes in each direction. There are also 2 traffic light regulated crossings located at Hälsovägen and Flemingsbergsleden (Kvål, 2019).

In 2017, there was an average of 18 600 cars travelling along Huddingevägen per day. The road is classified as a secondary route for transport of dangerous goods (Trafikverket, 2019a). This transport of dangerous goods along Huddingevägen is predominantly for transport to and from local facilities, such as the Karolinska University Hospital and gas station northeast of the area (Trafikverket, 2019a). Within Phase 2, the Flemingsberg train station is of particular interest, as it is centrally located in the area. The station receives traffic from different types of trains, such as commuter trains, regional trains, and long-distance trains. In 2018, the average amount of trains along the railway was estimated to be around 400 trains per day. Between the 2013 to 2018, an average of 1 700 train wagons carrying dangerous goods passed the station every year (Kvål, 2019). Additionally, a power line crosses Huddingevägen in the upper part of the area and continues north through to Flemingsbergs gård (Huddinge kommun, 2019a).

Northwest of the proposed development area, near Flemingsbergs gård, there is an area with high nature value (see Figure 5) (Henrikson, 2019). Flemingsbergs gård is an old building from the 17th century (1600s). The surrounding countryside, including the connection to the housing area of Grantorp and the area of Glömstadalen, is mentioned in Huddinge's cultural program. Grantorp, Flemingsbergs gård, and Södertörn University have also been designated as buildings with high value.

Precipitation within the area discharges towards the wetland-complex adjacent to the area in Phase 5-6 (Huddinge kommun, 2019a). The groundwater flows in the same direction as the surface water (Structor, 2019). The specific groundwater levels in this area have not been recorded. In general, the soil in the area is unclassified, but there are segments with clay-silt and filling material (SGU, 2019a). The average soil depth is between 10 to 20 metres (SGU, 2019b).

According to a noise density map from Huddinge Municipality (see Figure 6), developed by Tyréns (2019b), the noise level closest to the road and railway are estimated to be over 75 dBA per day, which is 20 dBA over the threshold limit for noise outside. The noise level in the remaining sections of Phase 2 are estimated to be between 60 and 75 dBA per day, which also exceeds the threshold value (Naturvårdsverket, 2019a).

The quality of the air can be measured by studying particles found in urban air, such as $PM_{2.5}$ and PM_{10}, particulate matter less than 2.5 and 10 µm in size, respectively. The concentration of PM_{10} per day in the area is estimated to be around 20-30 $\mu g/m^3$, which meets the Swedish Environmental Quality Objective target of 30 $\mu g/m^3$ (SLB analys, 2015).

2.2.3 Boundaries

The project phase lies within the four types of boundaries: a time, spatial, process, and subject boundary. With the exception of the differences explained in the following paragraphs, all boundaries stated in Section 1.4: *Boundaries and Assumptions* were applied for in this phase.

Phase 2 will take place following the expansion of the business district in Phase 1. Nevertheless, the exact start date is currently unknown as several decisions and agreements need to be made between the Municipality, state, and region before a final time plan is decided on.

Overall, this chapter focuses primarily on the area within Phase 2 (Figure 1 and Figure 9); however, also includes Flemingsbergs gård and areas with high nature value in close proximity, a maximum of 500 metres away. The Karolinska University Hospital, Södertörns University, and the nearest residential buildings are also included, due to their relatively high vulnerability to impacts on human health from noise and air pollution. A larger spatial scope for examination provides a more accurate idea of the effects on the environment, as the dynamic character of effects can be integrated. For example, noise and air pollutants from construction and traffic spread, therefore, it is necessary to consider the wider spatial areas that will be influenced.

2.3 Phase 3-4: Residence Area

2.3.1 Phase Description

Phase 3-4 of the Flemingsbergsdalen's plan program covers approximately 30 hectares[1] and is located in the northeastern section of the plan program. It is proposed that residential areas within Flemingsbergsdalen will attract approximately 5 000 new residents (Huddinge kommun, 2019a). This section, according to the plan, will have the largest concentration of housing combined with the lowest concentration of offices.

These buildings are expected to be built tightly knitted together (Figure 20) as compared with the Stockholm area, to create a mixture of a modern international urban feel with local accents. In this area, there will be approximately 3 000 apartments which will be built in a block structure with varying heights to maximise the utilisation of sunlight (Huddinge kommun, 2019a). Apartments are expected to have a high fluctuation of floor levels in the area. In addition, each apartment building will be equipped with a courtyard and a roof terrace (Huddinge kommun, 2019a).

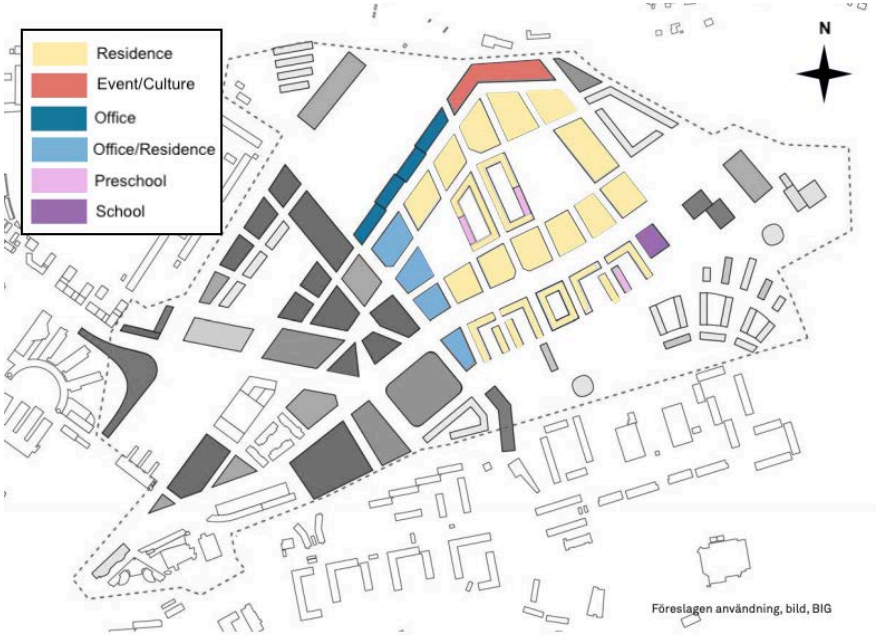


Figure 20. *Proposed use of new buildings (Huddinge kommun, 2019a; adapted by the authors).*

Offices are proposed to be built tall and placed as landmarks alongside roads, furthermore, they are going to act as a sound barrier for residential buildings from the incoming traffic from Huddingevägen and railway lines which run parallel to Phase 3-4 (Huddinge kommun, 2019a).

Residence in Flemingsbergs valley will be connected with different types of streets which will accommodate different styles of transportation (Huddinge kommun, 2019a). The city streets will have a high flow of cars,

[1] Measurement used from a meeting with Municipality

bicycles, and pedestrians, while the quarter streets will be constructed within the residential neighborhood and will have a lower level of traffic than the city streets. To encourage safe driving and lower the risk for accidents, the speed limit will be lowered and speed bumps will be constructed along the street. The pedestrian streets will be designed for walking, however, traffic within these streets will be allowed for the purpose of transporting goods (Huddinge kommun, 2019a). The Boulevard is the main street that will run parallel with the residential apartments in a north-south direction. This street will support all types of traffic with a priority on public transportation, the boulevard will also be equipped with well-developed sections for pedestrians and cyclists. The different types of traffic such as trams, cars, buses, cyclists, pedestrians will be distinctly separated by trees and curbs. The boulevard is expected to be a vibrant area since architectural designs of the apartment buildings will allow for shops to be placed on the bottom floors (Huddinge kommun, 2019a)

Flemingsbergsdalen caters to the safe development of children and their right to life by developing schools in the area. Within Phase 3-4, there are plans for developing one elementary school and three pre-schools which will accommodate 120 children each. Each school will accommodate approximately 15 m² of open space for each child, to ensure the space around the schools will be sufficient for the student's recreation (Huddinge kommun, 2019a).

This area also includes the provision of two parks known as Stadsdelsparken. These parks are proposed to be the largest in the area and are expected to be a frequent gathering point for residents and tourists. The parks will also function as a regulator for stormwater by purifying and delaying stormwater, managing heavy rainfall and support ecosystem services (Huddinge kommun, 2019a).

2.3.2 Baseline

Phase 3-4 is situated in the northern corner of the project area and is divided into 8 blocks of land, which are referred to by the block names; Transformatorn 2, Regulatorn 1 and 2, Batteriet 3-6, and Ackumulatorn 2 (Tyréns, 2019c; Figure 21). The area is sparsely vegetated and apart from the buildings located in the area, the site is broadly paved and tarmacked, essentially for parking lots and roads. Despite small patches of vegetation and some large trees (Figure 22), the estimated natural and biological value is set to low or absent (Henrikson, 2019). However, these green islands have been allowed to grow undisturbed for a longer period of time, and are thus suitable habitats for pollinators, insects and birds (Huddinge kommun, 2019a).

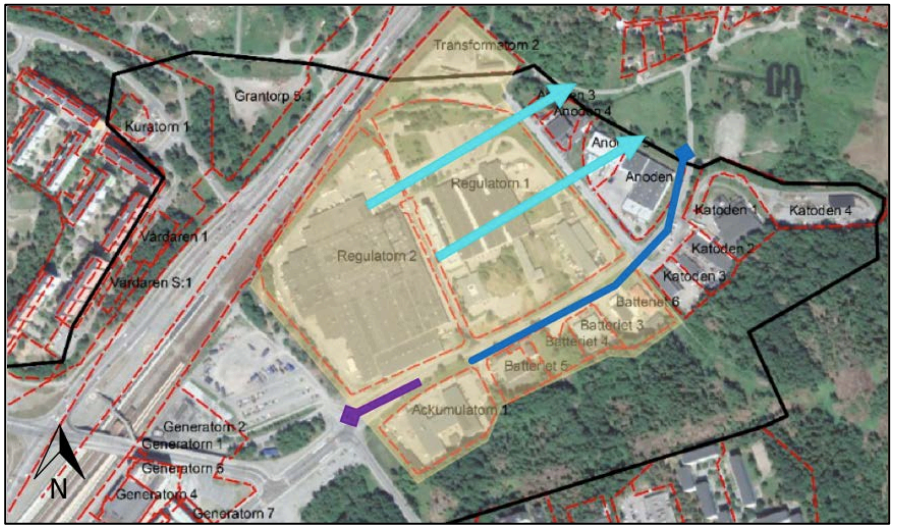


Figure 21. *Light blue arrows indicate major runoff pathways from the Regulator 1- and 2 premises towards a constructed wetland. Dark blue arrow highlights the runoff via Regulatorvägen down to Flemingsbergsdiket which is indirectly connected to Orlången. The purple mark highlights the run of direction and the*

accumulation of water at the intersection between Regulatorvägen and Kvarnängsvägen (Structor, 2019; Tyréns 2019a).



Figure 22. *Description of how the vegetation of phase 3-4 looks today. Picture taken on the 27th of November 2019. (credit: Judge M., 2019)*

Many of the current tenants residing in the area of Phase 3-4 are companies that are active in the building and industry sector e.g. drilling company and electronic components supplier. There are in addition several service companies such as a hostel, transportation companies and a library. Other tenants are a spirits company, a food import company, various office spaces and an elementary school. Transformatorn 2, which is located to the north, holds a switchgear facility.

According to maps from 1950 (Figure 23; Lantmäteriet, 2019), there is a historical artefact marked out in the middle part of Phase 3-4. The artefact could not visually be seen upon the site visit by an EIA-working group (performed on November 27th) nor is the identity of this artefact known (Gregorsson, 2019. Personal correspondence).



Figure 23. *Location of historical artefact according to maps from 1950 (Adapted from Lantmäteriet, 2019).*

The main county road with adjacent train tracks run past the area on the northeast side of the project site (Huddingevägen). Current speed limit for the road is 70 km/h. For all minor roads surrounding the phase area, the

limit is set to 40 km/h. The major road (Regulatorvägen) is also used by commuter busses (Figure 24). A survey of the noise in the area was conducted by Tyréns in 2019(b) (Figure 6). The threshold for acceptable noise for residential buildings has previously been set to 55 dB (Huddinge kommun, 2015), and, as seen in Figure 6, both properties of Regulatorn 1 and 2 currently exceeds the threshold. Two powerlines, with the respective kilovolts of 120 and 70, stretches over the area in the southeast to northwest direction. The production of electromagnetic radiation is



Figure 24. *Regulatorvägen (credit: Doppelmayr A., 2019).*

currently unknown and there is no current threshold or goal to reduce electromagnetic radiation (Huddinge kommun, 2019f).

The runoff direction for stormwater for Phase 3-4 is mainly to the north; to Flemingsbergsvikens wetland-complex then redirected to Orlången which is located outside of the project area. No constructed ditches to help the transportation of surface water are present in the area and for now the road Regulator vägen, located between Phases 3-4 and 5-6, currently acts as one of the main runoff routes leading to the Flemingsbergsdiket and further to the wetland-complex. These areas are particularly susceptible to high water levels and are at the present time fully saturated. Additional areas in the risk zone are located at the intersection of Regulatorvägen and Kvarnängsvägen (Figure 21). Groundwater levels lay between 23 and 24 metres above sea level in the Phase 3-4 area, and groundwater surface is at a depth of between 1.5 to 3 metre depth the surface. Groundwater has a similar route as the stormwater, directed towards the constructed wetland and ditches (Figure 25). Infiltration and percolation of stormwater are restricted but may take place in certain areas (Tyréns, 2019a).

The soil types of the area are mainly till but also consist of some loose clay, which has an average depth of 1 metre (Figure 25). The water quota of the clay ranges from 40 to 75 %. The area has been filled with aggregated materials of unknown origins and has at some sites a depth of 5 metres (Tyréns 2019a).

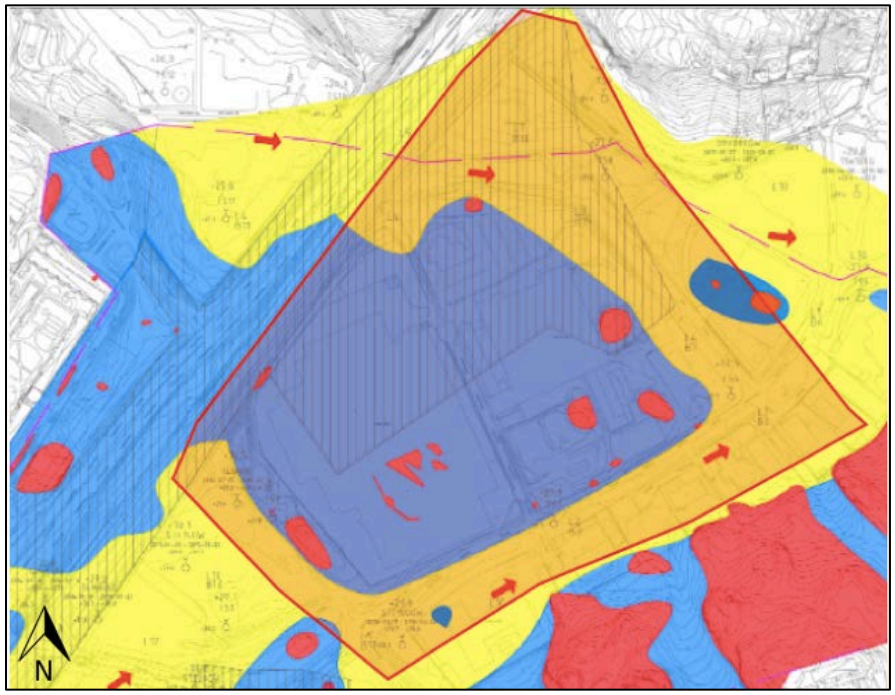


Figure 25. *Areas consisting of shallow bedrock are marked in red, areas consisting of loose clay is in yellow and blue represent areas consisting of till. Red arrows indicate suggested groundwater flow pathway (Adapted from Tyréns 2019a).*

Although no heavy production is currently being conducted in the area, according to a survey by Tyréns (2019c) the areas for Phase 3-4 are expected to have moderate to highly contaminated soil due to previous industrial activities. Previous activities included an internal fuel station and the production of electronic components. The area is known to have hosted oil cisterns, boiler rooms, and compressors. Investigated substances in contaminated soil consist of oils, heavy metals (such as mercury), PCBs, petroleum hydrocarbons, PAHs, as well as low levels of organic-, and chlorinated solvents. Contamination by chlorinated solvents in the groundwater has been confirmed (Structor, 2019). Many soil samples have been collected, but on a few sites in the area and thus, no complete overview of the area exists. (Tyréns, 2019c).

2.3.3 Boundaries

Phase 3-4 consists of three boundaries, categorized as temporal boundary, spatial boundary and subject boundary. For further information about the temporal boundaries, see Section: *1.4 Boundaries and Assumptions, subsection Temporal Boundaries*.

Spatial Boundaries

Phase 3-4 will consist of residential, commercial and recreational infrastructure. This part is sharing borders with Phase 2 and Phase 5-6. Huddingevägen and the railway lines located in the north-east part of the phase and the Boulevard, which is the main street passing through the area. All these, altogether, constitute the physical boundaries of this phase. Impact prediction, identification, and evaluation will be done within these boundaries only. However, some impacts like air pollution or emissions can have direct or indirect effects not only within the physical limits but also on adjoining areas. Thus, to avoid complexity and given the time constraint, any impact outside the physical boundaries will not be assessed. Likewise, there could be impacts on Phase 3-4 from encompassing areas and the same will not be considered either. Therefore, to explore the impacts on the natural environment, cultural environment and socio-economic environment within Phase 3-4, the physical boundaries will act as spatial boundaries.

Subject Boundaries

This area will be developed by demolishing the already existing buildings and factories. Due to this fact, the subject boundaries will include pollution, waste material generated by the demolition process and the soil contamination. The area is not very densely vegetated due to pre-existing structures, thus clearing off trees is not required. The two power lines passing through the area could also pose some threat to the safety of people (Avatare Kemmlert, 2019. Personal correspondence). Health, safety, noise, housing, employment, and equality will be assessed as well.

2.4 Phase 5-6: Recreational Parks and Schools

2.4.1 Phase Description

Phase 5-6 of the Flemingsbergsdalen project are mainly comprised of parks for recreation, preschools, schools and residential areas, and are located in the eastern outskirts of the entire project area. The eastern boundary of Phase 6 will face the new road Tvärförbindelsen and will therefore be exposed to noise pollution and light pollution among other things.

An artificially created pond for purification and retention purposes will be constructed in the area towards the wetland (Huddinge kommun, 2019a). The intention is that all the stormwater for all of Flemingsbergsdalen will be diverted towards the pond before continuing to the wetland and then to lake Orlången. Northwest of the pond, residential houses with a green courtyard will be built. The houses will be constructed in height section to enable and maximise light penetration. On the opposite side, there will be a new school and sports centre. The school is one of three that will be built in the project area. There will also be preschools built to accommodate the residents of the area. As the need for fun and engaging physical activity is important for children there will be an activity square located closely to the schools for easy access.

Outside the sport centre a technical building, necessary for the new road Tvärförbindelsen, will be situated. The construction of Tvärförbindelsen is planned to be initiated sometime between 2021 to 2023 and the duration of the construction is estimated to continue for 8 years, which corresponds to finalization of the project between 2029 to 2031 (Trafikverket, 2019b). The construction of Phase 6 will not be developed before that, therefore several uncertainties and unpredicted impacts may arise in the area. Closer to the railway there are plans for a logistics centre, however, it is not fully decided where it should be located and the complete use of this building is not set yet. The intention is to place a waste vacuum station and a recycling station to minimize transport of waste and other materials.

A city park is to be located in the middle of the Phase 5 area, the park will utilise the natural slope of the area, and is meant to integrate nature with a more landscaped park. Similar to the activity square this park aims to enable an area for both recreation, physical play, and encourage social meetings for both children and adults alike. On the project plan illustration, two round structures are visible. These structures are meant to be lookout points and not actual buildings (Figure 26).



***Figure 26**. Illustration of the proposed Phase 5-6 project area. A part of the Flemingsbergdalen wetland-complex can be seen northeast of the project area. (Google Maps, 2019, Huddinge kommun, 2019a. Illustrated by Sara Hedström 2019.)*

2.4.2 Baseline

Phase 5 currently consists of an industrial area with no private housings. The area was developed during a period of 30 years, between the 1980's to present. Current operating activities are as following; a stonework company, logistic company, bakery, car repair, pump service, recycling central, and sheet metal warehouse. Some of these have the rights to deal with flammables, such as SRV Återvinning AB, Lantmännen Unibake, and Bilverkstad (Kvål, 2019). There is also a landfill in the southern part of the forest (Olsson, 2019). Observations from the site shows evidence of some daytime activity, though the forest has traces of campers where trash is scattered around in the nature area.

Outside the southern border of the project area there is a multi-storey housing area called Visättra. North of the project area there is single housing area, Solgård. The northern area is separated by a wetland and grass area. Phase 5-6 is largely adjacent to Phase 4 but does also connect with Phase 1-3 (Huddinge kommun, 2019a).

There are 220 kV airborne power lines located in the forest, these can be seen as a straight line without trees in the map (Figure 26). They connect to a transformation station outside Phase 5's boundary to the north west. According to personal communication with a staff-member at the Huddinge Service Centre, these powerlines will be removed in the coming years.

Noise from the adjacent industrial area to Phase 5 was observed during the site visit. Noise from the railway and motorway has also been detected to affect the area. Mostly in the northwestern side of Phase 6 with dBa between 60-65 (measured 2 metres above ground), there are lower levels of noise in the rest of area (Engström and Torehammar, 2013).

The forest, located in Phase 5, is comprised of a coniferous forest mixed with deciduous trees of low to medium age, which was observed during the site visit. The topography of the forest is elevated with exposed bedrock. The natural value classification of the forest has been assessed to three, which refers to a significant environmental value, and four, which refers to some environmental value (Figure 27). There are also some red listed

species in this area, however information about the specific species is not accessible (Huddinge kommun, 2019a). During the site visit hare droppings were observed which shows that there is some larger wildlife in the forest. There were also wild trails, it can be assumed these were created by the forest wildlife. Traces of beaver activity were observed in close proximity to the wetland.

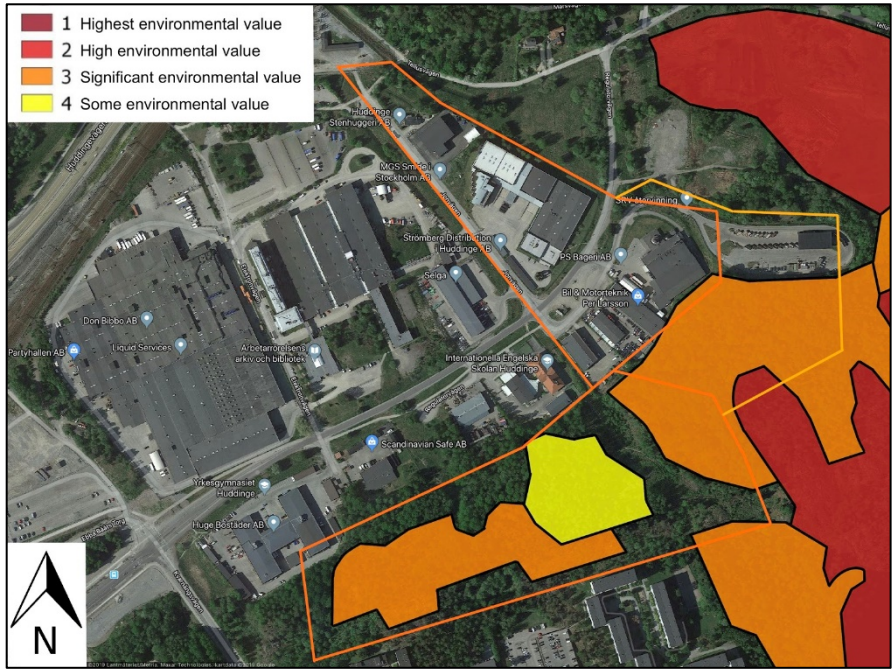


Figure 27. *Illustration of Phases 5-6, with the ecological value assessment made by Ekologigruppen. (Google Maps, 2019, Huddinge kommun, 2019a. Illustrated by Sara Hedström, 2019.)*

East of the project area, there is a constructed wetland is situated. Stormwater from the catchment area flows to the wetland and then further on to lake Orlången and eventually out in the Baltic sea. Lake Orlången is heavily eutrophicated and therefore in 1995 the 9 000 m^2 large wetland was constructed to reduce the amount of nutrients reaching lake Orlången. The whole project area lies within the catchment of the wetland. The stormwater entering the wetland is passing through an oil separating filter, filtrating surfaces, and sedimentation ponds before coming into the main wetland complex. The retention time in the wetland is six days on average, but vary a lot during the year due to the runoff amount. Measurements in Orlången has been taken from 1997 and forward. It shows that the phosphorus content has decreased from 69 µg/l 1997 to 41 µg/l in the year 2017. To reach good ecological status the Orlången needs to reach a yearly average of 23 g/l phosphorus (Norconsult, 2017).

The annual precipitation in the region is approximately 550 mm. Stormwater is currently managed by open ditches and other forms of pipes and culverts diverting the water towards Flemingsbergsdiket and the Flemingsbergsvikens wetland-complex. All of the surface and groundwater within Phase 5-6 is drained towards Flemingsbergsdiket and the Flemingsbergsvikens wetland-complex (Structor, 2019) (Figure 2 in Section 1.3.1: *Environmental and Natural Aspects,* subchapter *Soil features*). The majority of the total project area is also drained towards the north through Phase 5-6, first to a ditch and wetland, and thereafter discharging into Flemingsbergsviken and entering lake Orlången. The area for Phase 5-6 is subject to present challenges in handling the large amounts of generated stormwater.

The current groundwater level is approximately 23 to 24 metres above sea level and corresponds to 1.5 to 3 metres below ground level in this area, with an exception from the areas with high elevation where the groundwater table is situated much deeper (Structor, 2019). The

groundwater level is high and the prerequisites to handle large volumes of stormwater through percolation and infiltration is problematic. Since large areas of Phase 5-6 are primarily covered by thick layers of clay and large areas with exposed bedrock or bedrock with thin vegetation cover (ibid.). Phase 5-6 is mainly covered with forest stretching from Regulatorvägen and the residential area Visättra and bordering the nature reserve Flemingsbergsskogen (Figure 27). Regulatorvägen is located in the lowest point of a valley and stretches in a north-south direction with a slight decline towards the north and in the east the elevation increases towards the residential area Visättra. The predominant geological and topographical characteristics are not favorable for rapid infiltration and percolation (Figure 2).

Based on mapping of areas receiving large volumes and flows of water based on precipitation modelling conducted by WSP Bro och Vattenbyggnad (2018) shows that Regulatorvägen, Flemingsbergsdiket, and Flemingsbergsvikens wetland-complex are currently receiving large volumes of water. Regulatorvägen is draining the area towards Flemingsbergsdiket and Flemingsbergsvikens wetland-complex (Structor, 2019). The model output based on a 100-year precipitation occurrence event, even without a climatic factor, shows that it would generate flooding of parts of Regulatorvägen and roads nearby the ditch and wetland.

Trafikverket is planning to build Tvärförbindelse Södertörn, a new motorway between Vårby backe and Nynäsvägen. The planned road will pass north of Phase 5-6 and south of Flemingsbergsdiket and the Flemingbergsvikens wetland-complex (Structor, 2019). The existing stormwater drainage pathways will be cut off by this project and it is planned to be solved by constructing culver's under Tvärförbindelse Södertörn. According to Trafikverkets timeplan, the road is planned to be finalised by 2031 (ibid.).
The recipient Orlången is a part of the Tyrösåns catchment and is receiving the water discharging from the Flemingsbergsvikens wetland-complex. The current ecological status is classified as not satisfying and the chemical status is classified as bad. There are several EQS that the water body is exceeding. It is mainly eutrophication, lead and PBDE that are the reasons for this. The target is to reach the EQS standards by 2027 (VISS, 2019). It is identified that the pollution load to Orlången must decrease in order to reach the EQS within the set time frame (Huddinge kommun, 2019a).

2.4.3 Boundaries

The physical boundaries of Phase 5-6 are mainly defined by the phases spatial extent, see Figure 9. Despite the fact that the project is delimited to the project site, there are impacts that the project might pose on the surrounding environment that exceeds the physical borders of the project area. Therefore, the boundaries of Phase 5-6 that border non-project related areas will include 100 metres around the project area to ensure the assessment of potential direct and/or indirect impacts on the adjacent area. The project, as described in Section 2.4.1: Phase Description, will result in an increased area with impermeable surfaces that is likely to generate an increased amount of urban stormwater. The increase of stormwater will probably, depending on project design, increase the pressure on Flemingsbergsvikens wetland-complex and will therefore be included in the project's physical boundaries. Indirectly, the increased amount of stormwater and thereby potential transportation of sediments, pollutants, and nutrients to Flemingsbergsvikens wetland-complex. The wetland discharges into the recipient lake Orlången and it will therefore briefly be taken into consideration in this impact assessment.

3. Impact Assessment

The following chapter covers the impact assessment. The assessment is based on the division of the four different phases, described in Chapter 2. The first part of the project covers the impact assessment of the planned project (Section 3.1) followed by the Zero Alternative (Section 3.3) and Plus Alternative (Section 3.4).

3.1 Planned Project

3.1.1 Phase 1: City Centre

3.1.1.1 Natural Environment

Biodiversity

During the construction of Phase 1, the forest located between Visättra and Björnkullavägen (Figure 28) will be deforested due to the construction of infrastructure and buildings. The road, Kvarnängsvägen, will be moved approximately 25 m northeast-east to make space for the event centre and residential buildings, which will also interfere with the green areas on the eastern side of Kvarnängsvägen. Two event and culture buildings, an office building and a residential building will be constructed, in place of the forest, according to the plan program. The existing forest is of boreal character with some deciduous trees such as hazel, birch and aspen, but the phase's biodiversity is otherwise low because the forest is species-poor. The forest does not contain any threatened or red-listed species, nor does it contain any other species of specific ecological value (Ekologigruppen, 2018). Thus, the forest is assessed to be of natural value 4, according to the NVI-method in agreement with SIS-standard SS 199000:2014 (Ekologigruppen, 2018; Svenska Institutet för standarder, 2019). Evaluation of the impacts for the constructional phase was found to be minor adverse, eventhough the forest can be of importance for local biodiversity, it is of no significance on a regional, national or global scale (Ekologigruppen, 2018). However, since biodiversity can be defined at different levels (species- and ecosystem level), potential adverse effects from the removal of the forest on other ecosystems in the proximity should be considered to ensure no ecological consequences on the neighbouring nature reserve.



Figure 28. *The forest located in Phase 1 with natural value of 4 (Adapted from Lantmäteriet/Metria, 2019).*

The construction of the city and forest removal can result in more habitat fragmentation and less connectivity between the two green areas, Bornsjökilen and Hanvedenkilen, located to the north and south of Flemingsberg, respectively. To maintain biodiversity, it's important to conserve or create connectivity between natural environments, which can be done by creating corridors or stepping stones of green spaces (Beninde et al., 2015). The construction of new cities is one of the largest threats and negative impacts to biodiversity, due to landscape fragmentation (Seto et al., 2012). To counter this, the Municipality plans to create green spaces within Phase 1, by adding trees along streets and other green spaces such as green rooftops on several of the buildings. Green rooftops in urban environments have been shown to work as habitat for several taxa, especially insects, spiders, plants, some bird species, and even for rare and

endangered species (Getter and Rowe, 2006). To be able to maintain biodiversity through the use of green spaces, it is important to consider their spatial requirements, as there is limited space on the rooftops. In addition, only certain types of vegetation can be grown on green roofs, which further affect the quality and types of potential habitat (Mayrand and Clergeau, 2018).

When construction is finished and different buildings/activities are in operation, the noise and movement of people and traffic in the city could disturb the wildlife that are in close proximity to it (Newport et al. 2014). It is of great importance that the city is planned in such a way that the effects on animals and vegetation are minimized.

During construction, intense, constant lighting may be needed in order to carry out the work at all hours, in order to finish the project in time. According to the Municipality, Flemingsbergsdalen is planned to be an active and lively city all hours of the day, which implies that artificial lights will be needed at nighttime. Phase 1 will consist of mainly public and commercial buildings, performing arts, and other cultural activities which will further contribute to light pollution. Studies have shown that a variety of taxa are affected by artificial lights, such as insects, fish, bats and other mammals, birds, amphibians, and even plants (Rich and Longcore, 2006). The influx of artrifical light causes behavioural and physiological changes in species because their circadian rhythms are disrupted. This potentially has quite detrimental ecological consequences, especially for nocturnal animals (Owens et al., 2018). Since Flemingsbergsdalen and Phase 1 are located near the nature reserve, it is important to take the above effects into consideration when planning the city's lighting, in order to minimize the effects on the local biodiversity.

Air Quality

During the construction phase, some new roads will be built. As mentioned above, Kvarnängsvägen will be moved from its current location and the Regulator road will be expanded. Considering these changes, the area could be affected by dust if mitigation measures are not applied. In addition, odour and chemicals from asphalting could affect the air quality in this area, but only for a short period. For example, bitumen smoke, hydrogen sulphide and amines will be emitted during asphalt production and placement. The levels of these should not exceed the recommended values (Asfaltboken, 2019). In addition, within the construction phase, concrete and cement will be used in the construction of new buildings. The production of concrete will cause carbon dioxide and nitrous oxide to be emitted into the atmosphere, which will have an effect on the area's air quality, but only short term (Mosca et al., 2014). These effects will only be during the construction phase and are therefore considered to be a minor adverse.

In Phase 1, there will be some movement of material after excavation because of new building construction in this area, which could cause dust to affect the air quality. Therefore, it is important to apply suitable mitigation measures during this part of the construction. These effects will only be for a short period of time and are therefore assumed to be minor adverse.

The consequences on the air quality are both short and long term. Considering the short-term timeframe, mitigation measures could be applied. The long-term consequences are due to emissions from the use of heavy machinery, asphalting during construction and cars and trains in the area today. These can be mitigated, but when released into the

atmosphere, have a long term, irreversible effect that can affect local, regional and global scales. Although it may be on a global scale, the emissions resulting from the phase are not major, therefore, we assume that the impact significance will be minor adverse.

Where the new arena will be built close to Regulatorvägen and Kvarnängsvägen some unexploited area will become exploited, due to the small area that will be affected, in comparison to the rest of the phase. There is also no demolition of current building in phase one. Due to this, the significance of this impact is assumed to be neglectable.

Each of the buildings in the phase, will have a negligible impact on the air quality by themselves. If the entire city centre is considered with its sealed surfaces, this could significantly affect the impact rating given to air quality. According to Oke (1981), urbanization leads to an alteration in the physical environment which can lead to a change in the energy exchange and thermal conditions. The building materials, city layout, wind conditions, anthropogenic heat and air pollutants are all features that can change the local climate in urban areas (ibid.). To avoid “heat islands” in this part of the city, the buildings should be built of materials that do not absorb the heat too much and the wind conditions should also be considered. Due to increased population density and the tall and dense urban structures, the air quality will be affected. It is assumed that the significance therefore will be minor adverse. But if the impacts of the buildings are just looked at as a structure, without population, the significance is neglectable.

Today, Flemingsberg is designed for car traffic, but when Phase 1 is completed, the goal for 2030 is that 70 % of the transportation in Flemingsberg should be by pedestrians, cyclists and public transportation. In the future, the car traffic should mainly be located on the boulevard of Regulatorvägen. On the other roads in Phase 1, where car traffic is appropriate, such as the block streets, the roads will mainly be used for parking, which will be characterized with a lower traffic speed and have lower frequency of cars passing through (Tyréns, 2019d). Even though Flemingsberg will increase the amount of sustainable transportation it supports, it is important to consider the growing population, which will probably increase the car traffic of some roads and the number of train departures in the area, which could affect the air quality. The significance is therefore assumed to be minor adverse, if the Municipality can reach their sustainability goals for transportation.

The emissions from the railways are mostly from metal particles that flake off during repeated use of rails, contact lines, wheels and brakes. According to Trafikverket (2019c), the current values of metal particulates from transport use do not exceed EU environmental quality standards. The range of particulates reach 50-100 metre from the railway. According to Trafikverket (2019c), the level of inhalable particles from the Flemingsberg railways (PM_{10}), is safely within the European Union environmental quality standards. With the increase in departures of trains, the levels of pollutants can change and it is therefore assumed that the significance is minor adverse.

With the increasing devastation effects of air pollution on human health in urban environments, minimising air pollution as well as improving air quality has become crucial globally with regards to addressing health issues (Hewitt *et al*., 2019). The adoption of green infrastructure (GI) in urban developments has been viewed as a favourable solution to urban air pollution because of the environmental benefits which include mitigating air pollution, reducing ground-level ozone formation and enhancing urban air quality, whilst not interfering with the activities that cause air pollution

(ibid.). GI is a priority for this development, especially with the consideration of climate adaptation and mitigation measures. In the operational phase there will be green roofs and courtyards within the residential areas and along the roads there will be tree alleys. With these new green areas within the urban structure the air quality could be improved. According to the World Health Organization (2019a), trees in urban areas can improve the air quality because they produce oxygen and simultaneously take care of harmful air pollutants and airborne particulate matter. By using green cover in urban areas, trees can provide cool temperatures and provide shade during warm days to the residents. This could be a helpful way to reduce heat-related illnesses for the city's residents (Wolch et al. 2014). Even though trees can have a beneficial effect in urban areas, they can also have a negative effect on the air quality. Vegetation along roadsides can have a negative effect on the air quality because they can trap the emissions from cars. This could increase the concentration of pollutants in the air (Vos et al., 2013). It is therefore difficult to decide how efficient plants are when cleaning the air. It is assumed that the trees will not be planted too close to each other and therefore the significance is minor beneficial.

Surface water

Vegetation plays a critical role by reducing stormwater runoff, facilitating water infiltration into the soil and ultimately contributing to the groundwater table (State of Indiana Stormwater Manual, 2007). The construction phase involves site preparation activities such as vegetation clearing, soil excavation and grading. These activities can temporarily alter drainage and surface runoff patterns due to accumulation of sediments (from eroded piles of construction soil) in the stormwater infrastructure. A patch of forest on a steep slope bordering the Visättra area will be cleared to make way for the construction of the sports centre. Such landscape alterations will expose soils and make them susceptible to erosion (USGS, 2019). Vegetation litter is essential for the formation of soil structures through the addition of humus, which ultimately promotes surface water infiltration, as these materials act as sponges to absorb surface runoff (State of Indiana Stormwater Manual, 2007). To compensate for the loss of vegetation, the Municipality plans to incorporate green spaces within Phase 1, by including courtyards and green rooftops in the design (Huddinge kommun, 2019a). Green rooftops in urban environments act as infiltration surfaces, thus, minimizing stormwater runoff that will reach the natural drainage systems such as wetlands. However, there still will be more runoff from the roofs, when compared to natural vegetation because the vegetation has higher evapotranspiration than green roofs.

Urban landscapes are characterised by numerous impermeable surfaces associated with the infrastructure such as roads, parking lots and pedestrian walkways (State of Indiana Stormwater Manual, 2007). Consequently, the key hydrological impacts including peak surface runoff, associated with large-scale development projects (e.g. Flemingsbergsdalen) and urban environments are often associated with increased compact and impermeable surfaces, which are attributed to the use of heavy machinery and paving (Gorani 2017; State of Indiana Stormwater Manual, 2007). The parking of ICA Maxi that is located between Björnkullavägen and the railway is today pointed out as having low elevation which means that flooding can occur with heavy rainfall because evapotranspiration is decreased due to conversion of vegetated areas to paved surfaces. When this area is rebuilt, the runoff problems for this area needs to be considered according to the survey conducted in 2019 by Structor. In addition, the increasing number of residents in the phase will likely produce a lot of waste water during operation, which may affect local and regional water quality, especially through the fluxes of pollutants that are not regularly

removed in wastewater treatment plants, such as pharmaceutical residues, micro plastics and certain organic pollutants (Baresel *et al.*, 2015). This results in changes in natural runoff patterns, potentially increased risks of flash floods in the city (USGS, 2019) and increased waterstorm flow volumes reaching the wetland. Reduced infiltration could also mean little to no addition to the groundwater table (USGS, 2019); it is important to note that although surface water and groundwater are evaluated separately for the scope of this development, the two are intrinsically linked.

Groundwater

Spilled pollutants such as oil from vehicles and equipment, chemicals from construction materials and other contaminants can leach into the soil through infiltration. Runoff is redirected through stormwater drainage system into the wetland and as a result, pollutes the natural drainage system. Even though hydrological impacts are likely to increase, these impacts are considered to be minor adverse (-) because majority of the open spaces within the Phase 1 development area are currently paved and tarmacked (Figure 13), however, adequate stormwater management for the city centre would still be critical for mitigation of these impacts.

During the construction of transport and buildings, the inflow of groundwater in excavation pits must be abstracted, before any building foundations are to be laid. This digging may cause undesired drawdown of the groundwater, which can adversely affect its quality and ability to supply nearby streams (Ridgway et al., 2016), among other quality issues. The coarser the material used to construct the road, the faster that fluid can permeate the road and affect the local groundwater reservoirs (Rasul, 2018) There is also potential for the placement of buildings, transport and roads to change the flow paths of the groundwater temporarily (ibid.). As land and debris is moved during construction, any point (i.e. local) contamination (e.g. heavy metals) currently present in the soils, has the potential to leach into the surface and groundwater via streams, which can easily affect ground-water quality (Boateng, 2019). In particular, care should be taken if soils that are exhumed contain high proportions of sulphate, which may become acid generating under oxidizing conditions (SGU, 2019c). This is especially important where streams seep to groundwater, which can cause the distribution of the pollutant to develop into a “plume”, which is then transported to the receiving surface water body (USGS, 2016). Due to the relatively short timespan of the construction period, the impacts have been considered to be minor adverse. The exploitation of unused areas was assessed to have a minor adverse impact on the local groundwater because groundwater will be exposed to and polluted by the asphalt used to pave the roads, especially if the pavement used is particularly porous.

Traffic will have a minor adverse impact on the groundwater in the phase because of the potential of substances (i.e. liquid fuel, deicing fluid and the constant wear of vehicular components) that end up on the roads and eventually end up in groundwater (Wang et al., 2018). Sealed surfaces will decrease the infiltration of water into the soil. As less infiltration takes place, soil moisture content decreases and groundwater levels will lower over time (Zwaagstra, 2014). This interaction results in a minor adverse impact.

Noise

During the construction phase, there will be a lot of noise emitting from the area, which causes discomfort and disturbance of human health. This will cause discomfort for quite some time, based on the status of construction. There will be worksite noise from the use of diesel power generators and

the movement of construction materials to and from the project site. Sound will emit from construction equipment when clearing site debris or waste products and the removal of the woodlands for construction of the sports centre. Traffic also causes noise, due to the movement of people from one location to another especially during rush hour. Therefore, this is a minor adverse significance as the noise will be short term. The effects of noise during the construction will create an impact on people's health as a result of noise-related depression, ear problems (such as tinnitus), and possibly heart problems (Munzel et al., 2014, Widen et al., 2004). Noise can also result in the migration of people away from Flemingsbergsdalen.

Swedish standard environmental code and the Planning and Building Act states that noise from railways, traffic, cars, etc should be within the limits of 55 dBA and 70 dBA measured from the facades of residential buildings (Naturvårdsverket, 2017a). Noise monitoring equipment is required at the site to monitor noise levels during this process (EASHW, 2003).

During the operational phase, the environment becomes peaceful and will have little to no noise, if properly organised. A few areas that might still emit or generate noise, may be: schools, event areas, restaurants, residential buildings, commercial buildings, and traffic. These noise levels can be controlled though. This makes the impact of residential, commercial and public facilities negligible.

During the construction phase, although a lot of vibrations will be felt, this has been assessed to be minor adverse as a result of the temporary time period of such vibrations. Below are some of the areas, where vibrations may come from, during the project:

1. During the use of heavy machinery and equipment (i.e tractors and trailers) during the construction.
2. The use of power generators, drilling into the ground with road saws or chainsaws.
3. Vibration emitted from the rolling of concrete or asphalt, filling of materials and installation of piling pads during road paving.
4. During the use of steel and concrete support in building foundations.
5. During air compressor and mobile generator use for light towers.

The effect of vibrations on the environment, buildings and people can sometimes be drastic, but most of the time are quite minor. Vibrations can cause buildings to shake and crack and soil to be disturbed. During the operation phase, there will be no more vibrations, which will no longer have any impact on the environment.

Soil

During the construction phase of the project, several aspects will impact the soil. The construction of transport infrastructure and buildings, use of heavy machinery and exploiting of unused areas will have minor adverse effects on soil quality because the construction equipment will cause soil compaction and increase the possibility of contamination spreading in the soil (Cocârţă et al., 2017). Construction may also cause minor erosion of topsoil if activities are undertaken, mainly during days of heavy rainfall and high winds. With the construction of buildings, in particular, the sports centre, it is mentioned that the soils will be conserved in their "natural state" but there is no indication of how this preservation will be conducted (Huddinge kommun, 2019a). The movement of land and debris will have a significant adverse impact on the soil because soil will be moved during excavation when building foundations are being constructed.

According to current plans, the soil of the phase will mostly be paved over and serve as the foundation of roads, city walkways and the business area. This means that the soil will not be affected by several aspects of the project in its operational phase, such as; public facilities, commercial building, residential building, waste generation or traffic. Green spaces are thought to have a minor beneficial effect on the soil that is present in those rooftop gardens because the garden's plant roots will increase the availability of water storage and soil infiltration (Xie et al, 2012). Despite this, the effect is only minor due to the limited number of green spaces planned (in this case, a few green rooftop gardens) in comparison to the paved (areas lacking vegetation) areas in the phase.

3.1.1.2 Cultural Environment

Cultural Heritage

To date, Huddinge Municipality has completed an inventory of culturally significant locations, which identified two buildings with architectural and culturally important values, the police station and train station. According to a recent survey, Flemingsbergs train station is no longer considered culturally significant (Huddinge Municipality, 2019a). The cultural value of the police station is recognised by the Municipality, but it will not be affected during the construction of the phase because it has been deemed to not be in the affected area according to the plan program (Huddinge kommun, 2019a). Therefore, the significance of impacts in relation to cultural heritage is considered negligible during the development phase. Regardless, if any artefacts or locations (within the phase) which are of significant interest and are discovered at any stage of development, they must be reported and preserved in the best way possible according to Naturvårdsverket (2015).

The only major cultural interest within Phase 1 is the police station, but it will not be affected during the operation phase by any of the proposed developments in the phase (public facilities, commercial buildings, residential buildings, the generation of wastes, sealed surfaces, traffic or green spaces), and as such has a negligible impact within the phase.

Visual Landscape

The visual landscape is today characterised by several big parking areas and a few buildings near the train station, which serves as the center of Flemingsberg. During the construction of new roads and buildings, the visual landscape will be affected due to building cranes, heavy machinery, dust and building construction. There will also be some movement of material that will affect the visual landscape. This will turn Flemingsberg centrum to a construction site until the project is completed. Due to the fact that construction is only short term, the significance is assessed to be minor adverse. The unexploited areas in phase one, according to the baseline, are very small part compared with the exploited areas. It is therefore assumed that the significance is minor adverse.

When Phase 1 is built, the landscape will have a new character compared to the situation today. Phase 1 is highlighted as the heart of the city and will be characterized with high rise, dense urban development for commercial businesses, residential buildings, and other public facilities. The event and sport arenas can affect the visibility in the area for people living in the city before construction (Huddinge kommun, 2019j). It is hard to assess the impact on the visual landscape because it is subjective as some people prefer the urban feel while others will prefer that the visual landscape consists of a more natural environment (He et al., 2005). In phase one, there will not be a lot of parks and green areas, but there will be some vegetation in courtyards, on roofs and alongside roads and in

some public areas. In the end, it will depend on people's opinions. It is assumed that the significance of the visual landscape is major beneficial in comparison to the baseline conditions, when Flemingsberg was a very uninspiring centre.

3.1.1.3 Socio-Economic Environment

One of the significant potential positive impacts with this development is the improved quality of life of Flemingsberg community. Quality of life is often subjective, but it can be defined by one's satisfaction with regards to accessible housing, adequate health care facilities, equality, employment opportunities, mental wellbeing and so forth (Theofilou, 2013; EUROSTAT, 2019). During the construction and operation phases of the development, two aspects that significantly improve quality of life have been identified; these are employment opportunities during the construction phase and the availability of housing and associated services during the operation phase.

Housing

Currently, one of the major social challenges facing the Municipality is the lack of housing, especially with the Municipality's increasing population and within Sweden as a whole (SCB, 2018a). Municipalities are required by law to adopt housing supply guidelines and programmes based on the area's estimated population growth, housing demand, economy, etc. (Andersson et al. 2012). The new apartments will improve the standards of living for the locals, by addressing the housing challenges.

According to Andersson *et al.* (2012), municipalities, with the support of the County Administrative Boards, are responsible for the provision of housing at regulated rates to ensure that everyone has a fair chance of gaining access to housing. Residential apartments planned for Phase 1 of the development, located at the junction of Regulatorvägen and Björnkullavägen, will be built to be suitable for children, students, the working class and elderly (Huddinge kommun, 2019a). People with children are more attracted to residential apartments, schools, businesses, services and cultural buildings near the city centre as this allows them to have access to all the facilities they need for better standards of living without having to have significant commuting time. These people are often called "young urban professional parents" who seek to start families, continue growing their careers whilst maintaining cultural and social life (Karsten, 2014). Therefore, the location of these apartments is convenient and crucial for such families who are interested in an urban lifestyle that will integrate all these life aspects deemed important to them. Furthermore, the location of these apartments is ideal for students and the working class since they are located near the universities, schools and business area. The materials that are going to be used for the construction of these buildings are energy efficient and they will have green spaces and roofs. This may be attractive to residents because of the "green building" status. Therefore, some of these apartments may have high rent costs, whilst others are to be subsidised to be affordable for most people. The overall significance of the development (post-construction) on housing is considered to be major beneficial.

The JS Held University (2019) states that "the majority of construction-related vibration typically occurs during the early phases of construction.''. The primary construction activities associated with vibrations include: site clearance and removal of vegetation, site grading and soil compaction as well as installation of deep foundations (JS Held University, 2019). All of the aforementioned activities will be undertaken during the Flemingsbergsdalen project construction phase. Therefore, during this phase of development, residents in the existing apartments - apartments

within the development area and those along the boundary in the Visättra; will be negatively affected by the noise and vibrations from the use of construction machinery. Accessing the Flemingshallen could take longer as some routes may be closed and traffic redirected. For these reasons, the significance of the impacts during construction is determined to be minor adverse.

Recreation

Recreational facilities already established in the area, such as the gym, library and cafés could potentially lose clientele during the construction phase due to noise disturbances and the inconvenience that might be caused by the temporary closure of certain routes. This will temporarily reduce the attractiveness of the area, which may cause people to be very reluctant to visit this area during the construction phase. There is a pathway that runs through the forest patch that is currently used by residents to reach the centre, which could be used as a nature walk (Figure 29). The construction of the sports centre will have a minor adverse effect, as it requires that a forest patch bordering Visättra be cleared. Clearing this patch would rob the locals of the opportunity to experience nature in an urban environment.

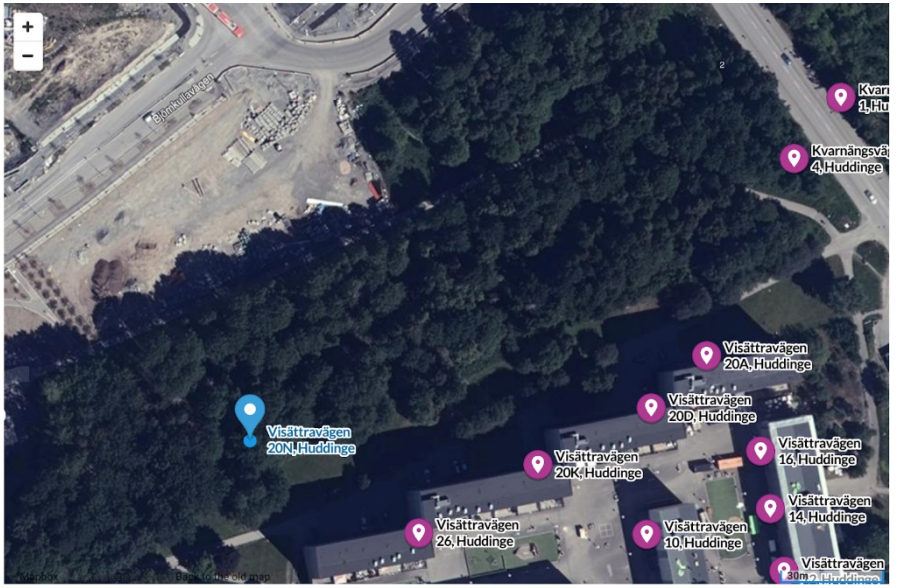


Figure 29. *The pathways within and along the forest patch bordering the Visättra area that are currently used by residents for leisure walks and serve as an alternate route to the centre and the train station. The forest patch will be cleared to make way for the sports centre and cultural buildings (Adapted from Lantmäteriet/Metria, 2019).*

When construction is complete, all buildings within the development (whether they are office or residential apartments), will have roof gardens, which may be useful for temperature control, design enhancement and serve as a place for recreational opportunities (Huddinge kommun, 2019b). Flemingsbergsdalen will become one of the most sustainable business districts in Sweden, and as such, the area's landscape architecture, in conjunction with green infrastructure will be of paramount importance. The city is designed in a way that will seamlessly incorporate nature through the addition of pedestrian walkways, quarter streets and the areas

around building flanked by trees and other plants. This allows humans to effortlessly connect with the natural environment (Figure 30). Buildings with convenience shops on the ground floor, such as coffee shops will havemore customers, which will promote economic growth within the city.



***Figure 30**. The vision of the city centre's central square (Huddinge kommun, 2019a).*

The development of the sports centre, events centre, cultural and leisure facilities will be beneficial to the Flemingsberg area as they will create opportunities for recreation and a social environment, which promotes social cohesion through social interaction at the recreation facilities. This relationship is illustrated in Figure A in Appendix 2 by Jennings and Bamkole (2019). Physical activities, as well as social interactions through the use of urban green spaces can yield positive health outcomes. Thus, this development will have major beneficial impacts on the Flemingsberg community.

Health

The sustainable development of cities (including green buildings) is considered to be of minimal risk to human health and the environment, since "green buildings are specially designed to cause less risk to human health and the environment through efficient use of energy, water, and other resources, with a concurrent reduction in waste, pollution and environmental impacts" (Rahman and Esa, 2014). However, the two main risks faced by humans which are associated with construction activities are: health problems due to dust and the feeling of discomfort due to the noise produced. Inhalation of dust due to excavation activities and exposure to air polluted by construction materials may have short- and long-term effects such as respiratory diseases, for example, asthma. Construction activities on previously contaminated soils may cause further spread of contamination (Cocârţă et al., 2017); which according to the University of the West of England, Bristol, may result in several health issues such as drop of IQ in children's development, kidney disease and bone disease (Science Communication Unit, University of the West of England, Bristol, 2013c). Similarly, exposure to irritating noise for prolonged periods can cause sleep disturbance which may lead to lack of focus which make individuals prone to accidental injury; tiredness, increased stress levels and other medical conditions (Glasson *et al*., 2012).

The residential apartments will be located between dense and high-rise buildings, which will limit the apartment's exposure to sunlight as they will be in the tall building's shadow the majority of the time. Shadows increase gloominess in an area and may negatively impact human health - as the lack of sunlight can cause an onset of depression. With all the services and facilities that will be available post-construction, there will be more opportunities to be physically and socially active which will improve wellbeing and positively impact human health. The significance of the development on health during the construction phase is considered to be minor adverse, however for the operational phase it is determined to be minor beneficial. This is due to the positive changes that the development

will bring to some of the social challenges in Flemingsberg including employment and housing, thus, perhaps reducing stress levels.

Safety

According to the City of Abbotsford (2013), it is possible to reduce criminal activities in urban environments by adopting a practical strategy known as Crime Prevention Through Environmental Design (CPTED), which is aimed at designing urban environments in a manner that will create attractive and active urban centres with a lively, urban feel. Essential to community safety, are social interactions within the city during both day and night times, increased pedestrian activity and the physical openness of the neighbourhood or the city environment. All these aspects are encompassed within the objectives of the Flemingsbergsdalen development, therefore, criminal activities may be reduced with increased job opportunities, increased social interactions and safety measures within the city centre. Within the city centre, quarter streets will be constructed with strict low speed limits. As area will have more pedestrians, the lower speed limits will reduce risks to road accidents within the city, which is vital because many schools are planned within the area. The overall significance of the potential risks to the safety of workers and the public within the development site is considered to be minor adverse during the construction phase and minor beneficial in the operation phase due to the potential reduction of criminal activities.

Equality

The equality of Phase 1 during construction, is assessed to be neglectable, since equality won't be affected by the construction. However, during the operation, the equality could be affected in several ways. The new public, commercial and residential buildings acting together like a city will create a feeling of togetherness for the community (Gang, 2016). Public and commercial buildings that are close to the residences create equality, regarding easy access between the residents of Flemingsberg. Also, paved surfaces in the city will increase the mobility and accessibility for people in wheelchairs and disabled persons, this is also addressed under the section "Accessibility and Connectivity". However, the development of the city can cause gentrification and segregation of Flemingsberg. New buildings in a coveted area usually have high accommodation prices (Davidson et al., 2010), which exclude some people from the area, resulting in more segregation. Because Flemingsberg is a working-class suburb, the development of the city can cause gentrification, where locals of the working class are forced out of the area because they cannot afford the new accommodation, affecting both residents and existing services. This implies that the new city is for the middle class instead of integrating the local working class. Although, when taking gentrification into account, the new housing and public buildings in the city will have an overall positive effect. This is due to the increased number of housing and services. Thus, the public, commercial and residential buildings and sealing of the surfaces is assessed to have a minor beneficial effect on the equality between the residents of Phase 1.

Phase 1 of the city will, when completed, offer and promote several types of transportation. At the boulevard, which will cross the phase from east to west, both cars, public transport (busses and trams), cyclists and pedestrians will be allowed. The two street types, "Stadsgata" and the "Kvartersgata" will also be present, allowing cars, busses, cyclists and pedestrians. All streets will offer improved conditions, especially for cyclists and pedestrians. Within the city centre "gångfartsområde" will be the main "street character", where the focus will be on pedestrians and cyclists, even though the cars are allowed as long as they keep a low speed (Figure 31)

(Huddinge kommun, 2019a). The focus on public transport via trams, cyclists and pedestrians both encourages fossil fuel-free transportation and facilitates better conditions for people using transportation other than cars. According to the Functionality goal (Prop. 2008/09:93) for transportation set by the Swedish Government, the Swedish transportation system should be designed in such a way that it ensures all people high quality transportation, no matter their gender, age, economic status or ableness (Regeringskansliet, 2008). Research by Torell et al. (2016), concluded that men use cars more than women, in comparison to women who use foot and public transportation more. Thus, investment in transportation types other than cars, increases not only equality between people using different transportation types, but also between men and women. The affordability of the transport, regarding age and economic status is addressed in Section *Accessibility and Connectivity* in this chapter. Equality regarding traffic is therefore assessed to be minor beneficial.



***Figure 31**. The hierarchy of roads in the area (Adapted from Huddinge kommun, 2019a).*

As green spaces in Phase 1 are limited, the green rooftops will most certainly not be accessible and the green spaces within a courtyard will most likely only be available for the residents living in the surrounding complexes. Because most of the buildings in Phase 1 are of public and commercial use, one could argue that the need of green spaces might not be significant. Since there's a trade-off between "money generating" practices and green spaces, a cost-benefit analysis could be conducted in order to evaluate the need for more green spaces (e.g. parks) in the phase. Green spaces, when considered in terms of equality, are therefore assessed to be minor adverse.

Employment

The creation of approximately 35 000 jobs and 5 000 new homes are just a few of the main goals for the Flemingsbergsdalen Program (Huddinge kommun, 2019a). Phase 1 construction is expected to commence in 2022 with completion scheduled for 2030. During this period, a significant labour force will be required for construction activities and as a result, there will be opportunities for temporary employment. Local residents should be given priority for unskilled labour, which will increase their employment opportunities and promote involvement during city development, which will result in improved connectedness. During the operational phase, Flemingsbergsdalen will have a wide-range of service offerings including; businesses, hotels, conference venues, sporting facilities (Huddinge kommun, 2019a). This will create ample employment opportunities in hospitality and skilled industries; for example, information and communications, finance and insurance, real estate services, law, economics, science and technology, and travel services (Huddinge kommun, 2019a). Considering the length of the construction phase and the magnitude of the project, the overall significance of this positive impact is determined to be minor beneficial (+) throughout all phases of development.

Accessibility and Connectivity

A vital part of municipal planning which should always be considered is the accessibility and connectivity of a development, in order to make it available for everyone within the community (Litman, 2019). This involves carefully crafted identification and assessment of the potential barriers on social groups in the community, and from this, strategies can be developed to address these challenges (Kilby and Smith, 2012). During the construction, all of the actions considered in this assessment (construction of transport, construction of buildings, movement of land and debris, demolition of current buildings, use of heavy machinery and exploiting of unused areas) will be minor adversely (-) affected. This is due to the roadblocks and demarcations that may occur in building sites, which will restrict access to other parts of the city during the construction period. To address this, accessibility is accessed according to requirements included in Chapter 8, Sections 1, 4, 7 and 9 Planning and Building Act in the building permit stage (Boverket, 2019). The Department of Economic and Social Affairs of the United Nations (2003) has several recommendations for considerations of planning using planning principles and design consideration (such as the surface, colour and layout) within the city.

In addition to keeping accessibility and connection central to the construction phase, these impacts will be seen in the operations phase. The addition and improvement of public facilities, commercial buildings, sealed surfaces, and traffic will have a major beneficial impact on accessibility and connection. The integration of public facilities and commercial buildings in a compact manner in the area will allow for its citizens to not have to travel far to access all of their daily needs met with limited travel time (Hull and O'Holleran, 2014). This allows for various social groups to be included and will encourage those groups to interact more if services are accessible to everyone with the minimum effort needed (Whole Building Design Guide Accessible Committee, 2019). Sealed surfaces allow citizens (in particular those with limited mobility, elderly and children) to navigate spaces without having to worry about mapping and avoiding certain routes in search of a destination (Salman, 2018). The addition of traffic will increase the reachability of the entire phase by making a range of transportation modes available and attractive for everyone, such as bicycling (Firth, 2012). In particular, if one does not have access to a car, but they do have a bicycle, they can still get to their destination. Residential buildings will only have a

negligible impact on the accessibility of the phase because the physical buildings will not restrict access to other services in the city. Waste generation has a negligible impact in this phase because it does not affect any movement, mobility or connectivity of the phase and its inhabitants. The planning of green spaces is minor beneficial to accessibility and connectivity because although it brings many benefits (to be warranted rather majorly beneficial), the debate of physical access (whether a green space will be fully public, semi-private or private) is the major limitation to this scoring. In particular, the grey area of public (but with restricted access) green spaces which are “green space belonging to a residential subdivision that does not allow one beneficiary to exclude others” (Le Texier et al., 2018). Ideally, access to all green spaces in the stage should be fully public, in order to allow the greatest degree of inclusivity and access.

Table 6. *Impact matrix showing the assessed impact significance levels for the corresponding actions and indicators in Phase 1.*

		Construction Phase				**Operation Phase**						
	Actions / Environmental Indicators	Construction of infrastructure	Movement of land	Demolition of buildings and removal of infrastructure	Exploiting unused areas	Public facilities	Commercial buildings	Residential buildings	Waste generation	Sealed surfaces	Traffic	Parks and green spaces
Natural	Biodiversity	-	-		-	-	-	-			-	+ +
	Air (quality)	-	-							-	-	+
	Surface water	-	-								-	+
	Ground water	-	-		-					-	-	
	Noise	-	-	-							-	
	Soil	-	- -		-							+
Cultural	Cultural heritage											
	Visual landscape	-	-		-	+ +	+ +	+ +				+ +
Socio-Economic	Housing	-	-	-		+ +	+ +	+ +			-	
	Recreation	-	-	-	-	+ +	+ +	+				
	Health	-	-	-	-	+	+	+			-	+
	Safety	-	-	-	-	+	+	+			-	
	Equality					+	+	+			+	-
	Employment	+	+	+	+	+	+				+	+
	Accessibility and Connectivity	-	-	-	-	+ +	+ +			+ +	+ +	+

3.1.2 Phase 2: Overlay Development

3.1.2.1 Natural Environment

Biodiversity

As mentioned in Section 2.2.2: *Baseline*, the entirety of the area within Phase 2 has little nature value. The majority of area consists of hardened surfaces, such as roads, railways, and buildings (Henriksson, 2019). Since all constructional activities are to take place on these hardened surfaces, the impact on biodiversity is considered to be negligible. According to the development plan, a sports centre is proposed to be built in the northern part of the project area. Since the area, at present, is covered by vegetation and an electrical tower, the tower will have to be demolished, vegetation cleared up, and surfaces sealed in order to proceed with construction. However, since the biodiversity of flora is low in the area, as it is mainly grass, and no red-listed species will be affected during construction or operation, the impact on biodiversity is considered to be negligible.

The noise produced during the construction period also has the possibility of interfering with communication between animals, thus hindering, and possibly threatening their lives (Sordello et al., 2019). However, aside from a few birds that reside in the area, it is assumed that the impact will be negligible, as the plants in the area will not be affected by noise. Due to lack of information at this time, it is recommended that a survey be done to identify whether or not the impact of construction noise on animals will be significant. In conclusion, due to the area's low nature value and lack of impact on threatened species, in both the construction phase and operation phase, the impact on biodiversity in Phase 2 is considered to be negligible.

Air Quality

All actions within the construction phase will produce a minorly adverse impact on air quality in the area, as the use of machinery and construction materials are likely to produce air pollutants such as particulate matter, NOx, and CO_2. Unknown substances currently reside within the soil in the area; therefore, pollutants may be released into the air when digging. The use of water will be crucial in minimising particle concentration in the air during demolition. The movement of land and exploitation of unused areas can also affect air quality, however, the extent is dependent on the methods that the developers choose to use. All air pollution produced within the construction phase is short-term and has the possibility to be mitigated, therefore the impacts on air quality are considered to be minorly adverse.

During the operational phase, traffic will negatively affect the air quality; however, less pollutants will be present than current day conditions, in the immediate areas above and beside the tunnel. The concentration of pollutants at the openings of the tunnel will depend on the design of the tunnel, which has not yet been decided on (Kallrén, 2019). The concentration of pollutants within the tunnel, however, are capable of being very high, as there are currently no environmental quality standards on air quality inside tunnels (Trafikverket, 2017b). It is difficult to quantify the exact impact that traffic will have on air pollution and further research is needed; however, traffic will have a majorly adverse impact on air quality throughout the entirety of the operational phase. Even if the tunnel provides a slight decrease in the amount of pollutants, traffic along Huddingevägen is expected to increase to around 29 000 cars per day by the year 2040, which will cause a sizable increase in traffic emissions (Henriksson and Fors, 2019).

Train traffic will also produce pollutants, predominantly in the form of metal particles released from rails, contact lines, wheels, and brakes (Trafikverket, 2019c). Such particles are heavy and usually stay within 50-100 metres of the railway, depending on weather and traffic conditions (Gustafsson et al., 2003). In tunnels, particle concentrations can be much higher due to limited space for air exchange. The kinds of particles released depend on the type of train. In Sweden, most trains use electricity, not diesel; therefore, only metal particles are released, and not combustion residue (Stroh et al., 2019). Particles from the outside of the tunnel, which can be sucked into the tunnel by trains through the "Piston Effect," also increase concentrations within the tunnel (Moreno, 2017). Moreover, studies show that particle release increases as a train brakes (Stroh et al., 2019). There are few studies about the health and air quality in tunnels, however, according to Harders (2016), the air within a tunnel is less dangerous than the air outside of a tunnel. Nevertheless, more research is needed. The average concentration of PM_{10} in underground train stations is between 100-400 µg/m^3, and the environmental quality norm for outside air is 40 µg/m^3 (Harders 2016). Thus, both cars and trains will affect air quality in majorly adverse ways; however, more information and research is needed, on aspects such as tunnel design and ventilation, in order to perform a full assessment on the impacts of traffic on air pollution.

According to the plan program, large buildings, such as the sports centre, will be built near roads in order to stop pollutants from further entering the area (Huddinge kommun, 2019a). Therefore, the significance is assumed to be majorly beneficial for public facility buildings within the area. In general, all buildings are capable of negatively affecting the air quality because pollutants can stay trapped in between buildings. Contrarily, buildings can also block pollutants coming into the city from bigger roads in the area. Since the design and size of buildings is still in its working phase, and the Municipality does not mention how buildings other than the sports centre will affect air quality, more research on this is required before construction commences. However, considering this uncertainty, it can be assumed that commercial and residential buildings in the area will have either a minor adverse or minor beneficial impact on air quality.

Surface water

During the construction phase, the building of infrastructure, movement of land, and demolition will cause deformation of surfaces and pollutant leakages. Heavy machinery and construction traffic will change the topography and compaction of soil, thus affecting the way surface water is transported. There is also a risk of oil or fuel spillage linked to the use of heavy machinery and demolition. Additionally, the use of certain construction materials such as copper, brass, and galvanized surfaces can cause pollution of the surface water (Structor, 2019). Depending on the size and exposure time, the spill can have varied effects on the quality of surface water. These actions are connected to short-term changes and will therefore, have a minor adverse impact on the surface water. As stated in Section 2.2.2: *Baseline*, precipitation in the area discharges to the wetland-complex, adjacent to the area in Phases 5 and 6. The surface water in the area will still drain into the wetland-complex during the construction phase; however, the amount of surface water that will reach the wetland-complex will increase due to the exploitation of unused areas, leading to more sealed surfaces with less infiltration potential. This will cause long-term, irreversible effects on surface water; therefore, the exploitation of unused areas is considered to have a majorly adverse effect on surface water.

Stormwater production is expected to increase in the operational phase, due to the addition of more impermeable surfaces within the area. These additions include the overlay and the railway. On the top of the overlay,

there will be a square with no infiltration capacity, except for flower beds. The area where the sports centre is to be located will also be converted from a surface with infiltration capacity to an impermeable surface. This means there will be less infiltration and more surfaces with stormwater generation potential. The project also plans to make minor changes to the topography, to enable surface water from the west of Huddingevägen to be led to the east, for handling and diversion. This means that even more stormwater will pass through the project area. However, this will also enable more water to be cleaned before it is released into the wetland-complex, and later, Lake Orlången.

Assuming the project is to implement green roofs on some, if not all, buildings, the buildings will generate less stormwater; thus, reducing the amount of burden on the wetland-complex, as more water can be cleaned and retained on the roofs. The area adjacent to a building also has the capability of enabling better stormwater solutions. If streets or courtyards use surfaces with infiltration abilities, the areas can clean and retain water before it reaches the recipient, which in this case is the wetland-complex. All buildings in the operational phase are therefore assumed to have a minor beneficial impact on stormwater because of their ability to both improve the quality and decrease the quantity of the surface water that reaches the wetland-complex.

Another majorly adverse impact on the quality of surface water is the presence of traffic. Traffic can emit particles and result in fuel and oil spills that can be transported through the surface water to the wetland-complex. According to a prognosis about the future number of cars along Huddingevägen, traffic is set to increase from 30 000 to 48 000 cars per year, by the year 2045 (Tyréns, 2019b). This means that the effects of traffic pollution on surface water will be long-term, and continue to increase as time passes.

Groundwater

During the construction phase, groundwater will be affected through pumping. Pumping groundwater may be necessary only during the construction phase, in order to keep it away from construction sites, or permanently, to keep it away from the foundations of operating buildings. Data on groundwater levels and quality are currently lacking in the project area and further measurements are needed to fully understand and account for the impact. Information about construction methods is also missing, which complicates the process of determining impacts that constructional activities may have on groundwater. However, if the construction of infrastructure also implies water operations, such as the pumping of groundwater, the project will be forced to apply for an approval of water operations in the environmental court. To be approved in the environmental court, an ambitious EIA has to be designed to assess all potential impacts that water operations may cause. The action is thus, considered to have a minor adverse effect, if groundwater will only be removed during the construction phase, as it will be short-term. However, the action is considered to have a major adverse effect on groundwater, if groundwater is to be removed from the area permanently, as it will result in a long-term impact. The pumping of groundwater is also capable of causing irreversible effects, such as subsidence on the ground that can cause uneven compaction and stress on the buildings. Additionally, destruction of flora and fauna in the area may occur due to the absence of water in the soil. Therefore, two colours, indicating minor adverse and major adverse impacts, are used in the significance matrix for the construction of infrastructure on groundwater.

The movement of land, through the excavation of soil and demolition of bedrock, are considered to have a major adverse effect on groundwater. The excavation of land can lead to contact with the groundwater level, and can cause unwanted water-filled sinks in the area. The groundwater itself, however, will not be affected in a long-term or irreversible way. Demolition of bedrock, on the other hand, can cause more severe effects on the groundwater quality, as the use of ammonium nitrate in the blasting process can produce nitrogen-rich water (SGU, 2013). Nitrogen-rich water that infiltrates into the area, and is transported within it, can cause acidification. Other concerns that arise when demolishing rock are risks of metal leaching and acidification, that may occur when sulfide-bearing rocks come into contact with air and water (Trafikverket, 2015). Although information about planned demolitions in the area have not been found, the movement of land is still considered to have a major adverse impact on the groundwater.

Removal of current infrastructure will have a minor adverse effect on the groundwater quantity and quality during the construction phase. The risk associated with removal is that elements that have been previously bound in the construction of the electrical tower will be exposed and possibly leak into the groundwater. Exploitation of unused areas can also cause pollution of groundwater, if the ground turns out to be polluted. The release of pollutants can occur, during exploitation, when soil comes into contact with air and water. This can lead to the transport and infiltration of polluted groundwater into the soil of surrounding areas. Soil measurements are therefore, encouraged to be taken before exploiting any unused areas to avoid this kind of effect on the groundwater.

The sealing of surfaces is considered to have a major adverse impact on groundwater production in the project area. The sealing of surfaces will cause more stormwater generation and change the distribution of groundwater generating areas. This, in turn, can cause flooding in other areas, as the water is forced to move through other transport ways. The action is considered to have a major adverse impact because once a surface is sealed, it is very difficult to restore its previous permeability; thus, resulting in an irreversible and long-term impact on groundwater. Changing groundwater generation areas can also lead to the absence of groundwater in some areas. This can cause irreversible effects, such as subsidence on the ground, which can result in uneven compaction and stress on buildings. The effects of traffic are considered to have a minor adverse impact on groundwater, as the potential release of pollutants from traffic incidents, such as oil spills, can infiltrate to the groundwater.

Noise

Since it is impossible to avoid noise during construction, all actions within the construction phase have been assessed to have a minor adverse impact on noise. However, it is important that the guideline values of noise at construction sites, obtained from Naturvårdsverket, are followed. The guideline values for building sites vary, depending on the time of day and day of the week. For housing areas, the guideline value outside between 07:00-19:00 is 60 dBA and 50 dBA between 19:00-22:00 on weekdays (Naturvårdsverket, 2019d). On weekends, the guideline value outside between 07:00-19.00 is 50 dBA and 45 dBA between 19:00-22:00 (ibid.). The value at night, from 22:00-07:00, can be up to 70 dBA (ibid.). The guideline value for noise that can be heard indoors is about 15 dBA lower than the values mentioned above (ibid.). According to Figure 6, the project area already exceeds the guideline values for noise, due to traffic along Huddingevägen and the railway. The area closest to the road and railway averages around 70-75 dBA, while the rest of the area averages around 60-75 dBA. Several sources of noise can cause an even greater impact on

human health. Depending on where people reside, noise levels may be higher, which can lead to majorly adverse effects on human health. However, thresholds of tolerable noise are subjective to each individual and animal, which make noise difficult to estimate.

Public facilities, commercial buildings, and residential buildings are all sources of noise. The noise from buildings can originate from both the activities operating in and around buildings. Additionally, the design and construction material of a building can influence the ability of the building to accumulate noise. Since the design of buildings in Phase 2 is currently unknown, it is difficult to properly estimate the effects on noise. Further research and detail are required on the matter. However, based on the current information, the effects of buildings on noise are considered to be minorly adverse.

Sealed surfaces can be considered to have an adverse impact on noise, because the noise absorbing function of softer surfaces will disappear when surfaces are sealed. The number of sealed surfaces in the area is expected to increase with the project, meaning that the noise level has the potential to increase. Therefore, the sealing of surfaces can be said to have minor adverse impact on noise.

As mentioned above, the dominant source of noise in the area is traffic. According to Tyréns (2019b), the future expansion of the high-speed train may lead to a need for noise reduction barriers, which may result in a decrease in noise levels from train traffic. The building of the overlay is considered to have a major beneficial effect on noise levels originating from the road and railway, as it will act as a lid. On top of the overlay, the main square will also be able to contribute to the reduction of noise with flower beds and soft surfaces that can absorb the noise; however, this green space is considered to only have a minor beneficial impact on noise. There is one concern with the overlay regarding noise, however, and that is that the noise from the tunnel will be channeled into one area, which can lead to even higher noise levels at the tunnel openings. Specific estimates regarding noise reduction capabilities of the overlay and potential noise levels at the tunnel openings are currently unavailable; therefore, further research is required. Regardless of this, traffic is still considered to have a major adverse impact on noise.

Soil

The process of sealing surfaces changes the original composition of soil, which in turn, negatively affects the ecological functions of soil (Scalenghe and Marsan, 2009). Sealed surfaces prevent material from permeating or escaping the soil (ibid.). Sealed surfaces also influence the water content of soil. When surfaces are sealed, the amount of water that infiltrates into and evaporates from the soil is reduced (Sela et al., 2012). Additionally, when soil is dry for a long period of time, evaporation decreases, which can compensate for the reduced infiltration, but affects the soil's water budget (ibid.). Therefore, considering that sealed surfaces play such a significant role on soil water budgets, compared to the natural state of soil, the impacts of sealing and sealed surfaces are considered to be majorly adverse.

Exposure of soil and rocks from the movement of land and construction of infrastructure allow for conditions in which erosion can occur (Chen et al., 2015). This is especially applicable on ramps, as a rise in slope increases soil erosion (Koulouri and Giourga, 2006). Less plants are able to grow when erosion increases, thus causing less residue back to the soil and a decrease in the soil's organic carbon storage (Gregorich et al., 1998). The decrease in organic carbon storage capacity may reduce soil quality and productivity

(ibid.). Additionally, as Huddingevägen is moved beneath the overlay and space for future railways is to be reserved, a huge volume of soil will be dug out. This will cause a change in stress distribution in the soil, soil displacement, and large-scale ground movement (Zheng and Diao, 2015). Thus, the movement of land and construction of infrastructure are considered to have majorly adverse impacts on soil.

Railway transport has the ability to emit organic contaminants and heavy metals into the soil and atmosphere (Malawska and Wiołkomirski, 2001). A significant amount of zinc, cadmium, and lead can leach into the soil from such transport (Zhang et al., 2012). These heavy metals can reside in the soil for a long period of time due to their low degradability (ibid.). This means that pollutants can accumulate in the soil, which increases soil pollution as time passes. Since traffic is expected to significantly increase in the future, traffic is considered to have a majorly adverse impact on soil.

3.1.2.2 Cultural Environment

Cultural Heritage

The various actions within the construction phase will not affect the cultural heritage of the area, as cultural heritage only considers the buildings themselves, and not the people in the surrounding area. According to the plan program, all buildings developed near Grantorp, one of the cultural heritage areas, will be low in height and consider existing buildings (Huddinge kommun, 2019a). The overlay will increase accessibility to Grantorp and Flemingsbergs gård. With an increase in population density and visitors to the area, as a result of new residential, commercial, and public facility buildings, Grantorp and Flemingsbergs gård may receive an influx of visitors. However, this is assuming that an increase in population will mean an increase in visitors to and appreciation of the area, which may not be the case. Further research is required in order to properly determine the effects; however, as of now, the entirety of Phase 2 can be said to have no significant impacts on cultural heritage.

Visual Landscape

The construction of infrastructure, movement of land, and exploitation of unused surfaces will have a minorly adverse impact on the visual landscape of Flemingsberg. To go forth with these actions, the use of heavy machinery is required, such as cranes and dump trucks. This, in conjunction with half-finished buildings and fragmented land, will not be visually pleasing to the eye. However, this will all be short-term. The one majorly beneficial impact that construction will have on Flemingsberg is that the electrical tower and power lines in the area will be removed, thus improving the visual landscape long-term.

Once construction is complete, the visual landscape will change significantly long-term. A visually pleasing landscape is classified as having a balance of different elements, such as terrain forms, habitats, roads, and buildings (Henriksson and Fors, 2017). Currently, Flemingsberg consists mainly of road and railway, therefore, it is not visually pleasing to look at. However, the vision for Flemingsbergsdalen is for it to be a mixed-use district, therefore, aligning with the definition of a visually pleasing landscape, as denoted by Trafikverket (2017b). Thus, the buildings and green space within the phase are expected to have a majorly beneficial impact on the visual landscape. Additionally, the overlay will remove the barrier that exists today, adding cohesion to the landscape, thus further enhancing it. According to the plan program, the new city will visually complement the surrounding areas as well (Huddinge kommun, 2019a).

3.1.2.3 Socio-Economic Environment

Housing

A substantial amount of soil must be dug out to lower Huddingevägen, which will result in large-scale ground movement (Zheng and Diao, 2015). This can affect the stability of structures above, thus having an adverse impact on existing housing. However, strict criteria must be followed for such actions, and precise measurements and calculations must be performed before construction begins in order to ensure safety. Although the probability of severe ground movement is unlikely, there is still a risk associated with this action. Therefore, the adverse impact produced by the movement of land can be considered minor. Construction of infrastructure will also be a source of ground vibration in the area. Use of heavy machinery and construction processes, such as piling and compaction of ground, will cause vibrations. Such vibrations can have a detrimental impact on the stability of already existing buildings (Hashad, 2015).

The apartments to be built, next to the new sports centre and on top of the overlay, will increase the amount of housing in the area. As Flemingsberg currently has a lack of housing, this will be majorly beneficial. In addition to the new residential buildings, a main square, travel centre, secondary school, and sports centre are to be built, which will increase the amount of amenities available to people in the area, thus increasing quality of life. An increase in building density will also aid in transforming Flemingsberg into a more prosperous and modern area. It is important to note, however, that as Flemingsberg becomes more attractive, more people may move to the area, thus causing a rise in housing prices.

Recreation

According to Haq (2011), most people only take part in recreational activities if they are in close proximity to their living area. Therefore, the addition of a sports centre, commercial buildings with ground level amenities, walkways and bike paths, and an urban green space will be beneficial to the Flemingsberg area. The development of a new sports centre provides a majorly beneficial impact on recreation, as there are currently no recreational facilities in the area. The sports centre in Phase 2 will be the largest in the area, allowing many people to use it. Participating in recreational activities, such as sport, "…contributes to: community health and wellbeing; confidence-building and empowerment; social integration and cohesion; national and cultural identity; and a reduction in crime and vandalism" (Grieve and Sherry, 2012). Therefore, providing the people of Flemingsberg with an outlet to participate in recreational activities will not only enhance recreation in the area, but may also provide long-term personal and communal socio-economic benefits.

Atop the overlay, a main square enclosed by commercial buildings with shops, restaurants, and other amenities is to be built. With an influx of new businesses, people in Flemingsberg will have a variety of recreational areas that they can utilize, thus enhancing the atmosphere and attractiveness of the area. This, in turn, aligns with one of the aims of the Flemingsbergsdalen project, which is to make the place more lively, in order to draw more people to the area (Huddinge kommun, 2019a). Altogether, the square will be a meeting place for recreation, which is majorly beneficial to the Flemingsberg area as it currently does not possess such a thing. Additionally, several sealed surfaces, in the form of cycling paths and pedestrian walkways, will be added to the project area. This will provide residents and visitors with more opportunities to go outside and

walk or cycle as they please, which is majorly beneficial, as the area is presently not very pedestrian- or bicycle-friendly.

As a lack of green space currently exists in the entirety of Flemingsberg, the addition of green spaces will be beneficial to the area. Urban green spaces are beneficial recreationally because they provide people with outdoor relaxation, enjoyment, and leisure opportunities on a daily basis (Haq, 2011). However, within Phase 2, the addition of urban green spaces is believed to only have a minor beneficial impact on the socio-economic environment, as the size and concentration of these green spaces are quite small. The main square appears to consist of a low percentage of actual green space, and more of trees surrounding small patches of green space (see Figure 32). According to Huddinge Municipality, the square will be an area with park-like qualities and urban greenery, rather than a full on park. Additionally, the green space surrounding the sports centre, in the northwestern corner of the phase area, seems to be of fair size; however, this has not been indicated by the Municipality to be of particular interest as a green area, and may be associated more with the recreational use of the sports centre.



Figure 32. *Visualization of the main square to be built atop the overlay (Huddinge kommun, 2019a).*

Health

As highlighted above in the Section 3.1.2.1: *Natural Environment* subchapter *Air Quality* respective *Noise*, all actions within the construction phase will have a minor adverse impact on air quality and noise; therefore, such actions will also have adverse impacts on human health. For instance, an increase in air pollutants can negatively affect the respiratory and cardiovascular systems (Abelsohn and Stieb, 2011). Additionally, if noise during the construction phase does not remain within the guideline values indicated by Naturvårdsverket, adverse health effects associated with exposure to high noise levels, such as cardiovascular disease, cognitive impairment in children, sleep disturbance, tinnitus, and annoyance, may arise (WHO, 2011). However, considering the impact of construction activities on air quality and noise are minorly adverse, the impacts on health are also considered to be minorly adverse.

The introduction of a new sports centre in the area will not only have a majorly beneficial impact on recreation, but also on health. The sports centre will allow residents of Flemingsberg to participate in various recreational activities. Recreational activities can be associated with both physical and mental health benefits, such as decreasing the risk of chronic diseases, boosting the immune system, improving life satisfaction, and relieving stress (California State Parks, 2005). This in turn, will provide long-term health benefits to the residents of Flemingsberg. In addition, the new commercial and residential buildings are capable of increasing quality of life in Flemingsberg, considering there are affordable housing and equal employment opportunities. In general, increasing access to socio-economic opportunities in an area increases connectivity between people and their locality (Hasan et al., 2017). Therefore, with more affordable housing options and more people living in the area, residents of Flemingsberg will feel more secure and connected to their community. This, in turn, will have a positive effect on mental health, as individuals will not have to worry about not feeling safe in their respective neighbourhoods. Furthermore, additional employment opportunities will allow for individuals to obtain a higher quality of life, as a study, done by Hultman et al. (2006), shows that unemployed individuals generally exhibit a poorer quality of life than employed individuals. Altogether, the positives that are associated with the operation of new public facilities, commercial buildings, and residential buildings can be classified as having major beneficial impacts on health.

Most of the area within Phase 2 is already covered by sealed surfaces; however, introducing newly sealed surfaces atop the overlay and in previously unused areas, such as the forested area in the northwestern corner, will have minor adverse to major beneficial impacts on health. Sealed surfaces in dense, urban areas retain and emit more heat through thermal absorption and radiation, respectively (Ward et al., 2016). The increased emissivity will make Flemingsberg warmer, in general, and more vulnerable to intense heat waves. Heat stress can have moderate to serious consequences on human health, "…such as lack of concentration, exhaustion, dehydration, circulatory disorder, and (...) death" (ibid.). Therefore, while sealed surfaces within the area are not increasing substantially, introducing new ones may increase the intensity of effects felt from a heat wave, thus causing adverse impacts on human health. It is important to note, however, that these effects will only be felt at higher temperatures; and since the average temperature in Flemingsberg during the summer is around 20 degrees Celsius, it is unlikely that the sealed surfaces will have a significant impact on health, unless extremities are present (Yr, 2019). Major beneficial impacts on health will also arise with additional sealed surfaces in the area, such as pedestrian walkways and cycling paths, which promote more active, rather than passive, modes of transport. Active modes of transport are considered healthier modes of transport, as they get people moving instead of sitting in vehicles; thus, improving individual health and creating a cleaner environment (Banister, 2008). Therefore, the addition of these pathways will allow for more opportunities for sustainable and healthy transport in the area.

An increase in road, train, bicycle, and pedestrian traffic are expected during the operational phase of the project, which are predicted to have minor adverse to major beneficial impacts on health in the Flemingsberg area. Noise from the road and railways are expected to increase as more vehicles pass through the area on a daily basis. As mentioned in Section *2.2.2: Baseline*, the noise levels near the road and railway are already 20 dbA above the threshold value for outside noise; therefore, a further increase in noise levels would have an adverse impact on health (Tyréns, 2019b). As mentioned above, in Section 3.1.2.1: *Natural Environment* Subchapter *Noise*, the tunnels forming segments of the overlay will act as

noise reduction mechanisms, as they will reduce sound within the project area and confine it inside the tunnels. However, at the tunnel openings, the effects of the increased noise will still be felt. Additionally, while the Solgård interchange seeks to displace some of the noise outside the city centre, the traffic passing through the city will still increase total noise levels. Therefore, while the tunnels and displacement of noise act as dampeners, an increase in noise will still mean a minor adverse impact on health. An increase in traffic along Huddingevägen also means an increase in exhaust fumes from vehicles. This will have an adverse effect on health, as, "Transport-induced emissions are linked to declining public health" (Banister, 2008). As mentioned in *Section 2.2.2: Baseline*, the particulate matter concentration in the area currently meets the Swedish Environmental Quality Objective target value; and although there will be an increase in transport-induced emissions from cars, a decrease in emissions within the city is also expected with a switch from more passive to active modes of transport. Aligning with one of the Municipality's visions for the project, Flemingsbergsdalen is to transform into a relatively car-free city (Huddinge kommun, 2019a). Transport in the area is currently dominated by cars, so the switch to walking, cycling, and public transport, will have a major beneficial impact on health. As mentioned above, active modes of transport benefit individual health and air quality. Utilizing active modes of transport will decrease total transport-induced emissions, thus increasing the quality of air in the area and providing a healthier living environment for those residing in Flemingsberg.

As mentioned above in the subheading *Recreation* in Section *3.1.2.3: Socio-Economic Environment*, Flemingsberg currently has a lack of green spaces; therefore, introducing green spaces will be beneficial to the city and its population. According to a study performed on Swedish cities, by Grahn and Stigsdotter (2003), people reported lower levels of stress when spending more time outdoors in urban green areas. Therefore, introducing the main square will be beneficial to the health and wellbeing of the population of Flemingsberg, as it will provide individuals with an outdoor spot for leisure and relaxation. However, because the concentration of greenery within the main square is quite low, the urban green space in Phase 2 is only considered to have a minor beneficial impact on health. Seeing as it is the only green space within the phase area, it is unlikely that the environmental benefits that often come with parks, such as improvements in air quality, will have a significant impact on human health (Haq, 2011). Thus, the main square will mainly provide benefits for mental health, rather than physical health.

Safety

All actions within the construction stage of Phase 2 are considered to have a minor adverse impact on safety in the Flemingsberg area. The most common construction hazards, resulting in injuries and fatalities, are "struck-by" and "caught-in" incidents (Stiehl, 2019). "Struck-by" incidents occur when individuals are hit directly by heavy machinery, such as a truck or crane, while "caught-in" incidents occur when harm is inflicted on an individual being caught between two objects, such as getting pinned against a wall by a heavy beam (ibid.). Because the use of heavy machinery is required to construct the proposed infrastructure, the risk of such incidents will be present. Construction of the overlay poses an additional risk of falling objects to all road and railway users during the construction period. This is due to the fact that large machinery will be used to lift and place heavy segments above Huddingevägen and the train station. Furthermore, ground vibrations caused by the use of heavy machinery will pose a safety risk to the stability of surrounding structures (Svinkin, 2008). In general, the construction in Phase 2 has the potential to endanger both the public and construction workers in the immediate area, as the

occurrence of an accident could result in detrimental consequences. However, while the scale of construction is quite large, the time span of construction is small, compared to the operational phase, and the likelihood of an accident occurring is quite low. It is also assumed that construction workers will follow safety protocol and measures to minimise and prevent the likelihood of hazards in the process. It is important to note that the hazards covered in this section are broad, and based on assumptions of methods used for construction. Therefore, further research and detail are required to determine the full range of consequences associated with all actions in the construction phase.

Due to the fact that the project is still in its early stages, it is still unclear how exactly the developers intend on lowering Huddingevägen. However, in order to do so, the existing road will most likely be demolished and underlying ground excavated. Demolition poses safety risks such as exposure to high levels of noise and falls due to uneven surfaces (Safe Work Australia, 2015). On the other hand, common hazards associated with excavation include undermining the stability of nearby structures, thus causing their collapse, and materials, people, and vehicles falling into the excavated area (Ai Solutions Limited, 2019). It is also assumed that traffic will have to be diverted in order to lower the road. This will increase traffic on other roads in the area, which will lead to the temporary displacement of the risk associated with dangerous goods transport along Huddingevägen. However, this will only be short-term and is confined to one area, therefore it can be considered quite minor.

In addition to the actions stated above, the power line in the northwestern corner will need to be removed, as it currently resides in the unused green area where the new sports centre is to be built. The removal of this power line is classified as an adverse impact, as power lines are associated with safety risks, such as rogue sparks flying in the area and downed lines (Svenska kraftnät, 2015). However, the decommissioning of the power line is only considered minor, as it is assumed that the workers will follow safety measures by turning off all electrical circuits and removing all infrastructure cautiously. Additionally, Svenska kraftnät has not experienced any serious accidents in the past 10 years, therefore the likelihood of an accident is low (2015).

As previously mentioned in Section *1.3.2: Socio-Economic and Public Health Aspects* under the subheadings *Segregation* and *Crime*, inequalities currently exist in Flemingsberg's socio-economic environment, thus making it an insecure area to live in (White Arkitekter, 2012). However, introducing new public facilities, commercial buildings, residential buildings, and green space, in the form of the main square, will increase safety long-term in the Flemingsberg area. According to the "Eyes on the Street" theory, dense communities with multi-uses, such as residential and commercial, encourage traffic on the streets (Wekerle, 2000). With an increase in population and traffic on the streets during the day and night, the community will feel safer, as it will deter criminal activity and provide "eyes on the streets". The new development will also increase the quality of life in the area, thus bettering socio-economic conditions in the area and reducing the likelihood of crime (Polismyndigheten, 2005). In addition to this, parks and green spaces can further increase safety, so long as they encourage active use of the area, which the main square seeks to do (ibid.). In general, the new development, in conjunction with an increase in local traffic, will provide a majorly beneficial impact to the area through a substantial increase in safety and security.

While the new development will provide an increased feeling of safety within the city, an increase in both road and train traffic is expected to

occur during the operational phase, thus bringing forth an increased risk in safety. Huddingevägen is considered a secondary transport route for dangerous goods; therefore, should an accident occur, its proximity to the city and train tracks may lead to serious consequences. Additionally, as mentioned in Section *2.2.2: Baseline*, approximately 1 700 train units carrying dangerous goods passed Flemingsberg station per year, from 2013-2018 (Kvål, 2019). Thus, with an expected increase in transport of dangerous goods, there is also an increased risk of an accident associated with dire consequences, such as the release of toxic gases or smoke from the tunnel openings dispersing to the adjacent areas (Kallrén, 2019). While the consequence of an accident from a dangerous goods transport vehicle would be detrimental to the area, the impact is only considered to be minorly adverse, due to the fact that the likelihood of an accident is not very high.

Equality

In general, urban inequalities or residential segregation are present in all sectors, such as education, transport, housing, and income, and are considered to cause disparity gaps in opportunity between specific population subgroups (Scarpa, 2016). Therefore, these inequalities are also associated with higher crime rates and lower degrees of inhabitant happiness (Glaeser et al., 2008). Although equality is not directly stated as a goal of the Flemingsbergsdalen planning program, it should be included in all decisions to ensure a sustainable living environment for all social groups. While the construction phase shows no impacts on equality, the operational phase exhibits minor to major beneficial impacts on equality. This, in particular, refers to the creation of new job and income opportunities, which aid in tackling unemployment and criminality, both locally and regionally. In addition, the planned educational institutions in Phase 2 will allow for equal opportunity to obtain a good education. Moreover, adequate housing for all levels of income will reduce the marginalisation of groups within residential areas. The proportion of social housing planned in the new residential areas must be further examined to prevent a division of the city into poor and rich residential districts. Moreover, the expansion of the public transport network, in conjunction with the new travel centre, will promote equality between groups, as it will ensure that people from all communities can use transportation. Additionally, since no cars will technically be required to access all services in the region, the stigmatisation associated with low-income households will be reduced.

Employment

The construction of office and business buildings is believed to have a minor to major beneficial impact on the socio-economic environment (see Table 7). Six office buildings are planned to be built on top of the overlay, corresponding to 20 % of all business buildings within the proposed project area. Moreover, a school, sports centre, travel centre, and possible university building are to be built, creating additional long-term employment opportunities. The expansion of the transport sector within the area also offers some additional employment opportunities for bus drivers and road maintenance staff, and is therefore considered to be of minor benefit. The exact number of workplaces is currently unknown; nevertheless, space for around 35 000 new workers is intended to be created for the entire project area (Huddinge Kommun, 2019a), which would correspond to about 10 000 jobs during the operation of Phase 2.
Not to be neglected are all short-term and indirectly provided jobs during the construction phase. This includes workers needed during the construction phase for aspects such as terrain modelling, building construction, planning, and architectural needs. This also has the ability to

strengthen the region's economy if materials and services from local companies are obtained.

Accessibility and Connectivity

Hasan et al. (2017) say that access to facilities, public services, and socio-economic opportunities play a crucial role in the growth of human settlements, and increase connectivity between people and regions. Thus, an increase in accessibility is associated with substantial socio-economic advantages, such as decreasing the median age and unemployment rate, as well as increasing the median household income (ibid.). In general, the degree to which a product, service, or environment is accessible and the cost of using public transport are indicators for how productive and competitive an area is (ibid.). Therefore, the results of the conducted project analysis show that the impacts on accessibility and connectivity during the construction phase are minorly adverse, while during the operation, the impacts can be classified as minorly to majorly beneficial.

The construction of the overlay and lowering of Huddingevägen will cause disruptions and delays of daily rail and road traffic leading to a short-term reduction of accessibility to Flemingsberg. Due to the lowering of Huddingevägen, large parts of the main road will have to be closed off, which make it necessary to redirect traffic. Consequently, an increase in travel times and noise and air pollution along detour routes will put new stressors on human health and well-being. In addition, the construction of the overlay will render large parts of Flemingsberg, such as the parking space next to the train tracks, unusable. Overall, further research is needed to identify the consequences of alternative traffic routes on travel times to and from Stockholm City, and on the usage of shopping facilities in Flemingsberg when accessibility is reduced.

However, accessibility and connectivity within Flemingsberg will experience major beneficial impacts during operation, as the overlay will overcome the current barrier that exists and connect the eastern and western parts of the city. In addition, the planned travel centre and increased capacity of Huddingevägen and the rail network will make major contributions to strengthening Flemingsberg's connections to the region. In terms of accessibility, sealed surfaces are considered to have a minorly beneficial impact on the area, as they offer more routes for pedestrians and bicycles to reach the city centre. As mentioned by Grieve and Sherry (2012), recreational facilities, such as the sports centre and restaurants and cafés on top of the overlay, are able to enhance social integration, cohesion, and promote a non-violent environment, thus increasing interpersonal connections and identity building.

Table 7. *Impact matrix showing the assessed impact significance levels for the corresponding actions and indicators in Phase 2.*

		Construction Phase				Operation Phase						
	Actions / Environmental Indicators	Construction of infrastructure	Movement of land	Demolition of buildings and removal of infrastructure	Exploiting unused areas	Public facilities	Commercial buildings	Residential buildings	Waste generation	Sealed surfaces	Traffic	Parks and green spaces
Natural	Biodiversity											
	Air (quality)	-	-	-	-	+	- +	- +			- -	
	Surface water	-	-	-	- -	+	+	+		- -	- -	
	Ground water	- - -	- -	-	-					- -	-	
	Noise	-	-	-	-	-	-	-		-	- -	+
	Soil	- -	- -		- -					- -	- -	
Cultural	Cultural heritage											
	Visual landscape	-	-	+ +	-	+ +	+ +	+ +				+ +
Socio-Economic	Housing	-	-			+ +	+ +	+ +				
	Recreation					+ +	+ +			+ +		+
	Health	-	-	-	-	+ +	+ +	+ +		- + +	- + +	+
	Safety	-	-	-	-	+ +	+ +	+ +			- + +	+
	Equality					+	+ +	+ +			+	
	Employment	+	+	+		+	+ +				+	
	Accessibility and Connectivity	-	-	-		+ +				+	+ +	

3.1.3 Phase 3-4: Residence Area

3.1.3.1 Natural Environment

Biodiversity

Despite the lack of green areas in Phase 3-4, those that do exist have been allowed to grow undisturbed for a longer period of time. This makes them suitable habitats for pollinators, birds, and insects. Aside from this, the area, as described in the baseline, consists mostly of hard surfaces such as asphalt and buildings. The new layout of Phase 3-4 will have a similar layout, albeit, an increase in the number of buildings and roads (Huddinge kommun, 2019a; Figure 1). The small green spaces that do exist will most likely be excavated during construction. However, if the proposed green areas (Figure 33) are thoughtfully designed and optimized to compensate for the loss of existing green spaces and increase suitable conditions, these small biotopes could have a small positive impact on the promotion of biodiversity during the operation of the area. These could contribute to the offset of fragmentation and act as a bridge between habitats.



Figure 33*. The Phase 3-4 area is marked in blue. Green courtyards are indicated in yellow and green areas (marked in green) represent city parks. Dashed blue arrows indicate proposed potential water runoff pathways (Adapted from Huddinge kommun, 2019a).*

Waste Generation and Traffic during Operational Stages

A consequence of an increase in population and movement in the Phase 3-4 area is an increase in waste generation and traffic. If not managed properly, waste can travel to the implemented green areas. However, it's likely that the type of waste produced, as compared to the present time, will be less hazardous as the industries that occupy the area relocate and are replaced with residential buildings and stores. Moreover, traffic in the

area could contribute to more noise and emissions which may have a negative impact on certain species.

Light Pollution

Several factors may affect the green areas created to promote biodiversity in Phase 3-4. One such impact has been identified as artificial light, *inter alia,* LED-lighting (Jägerbrand, A.K., 2018). The artificial light can originate from both the construction phase and the operational phase of the site; extensive artificial lighting from construction that will take place during dark hours and wintertime, and the illumination of buildings and roads during the operation of the residential area. The distribution of this light is potentially widespread, as the buildings located in Phase 3-4 are planned to be 20 stories high (Gregorsson, 2019. Personal correspondence). Any upward illumination will also contribute to the sky glow, which is also by default, widespread. The light pollution would have minor adverse effect on biodiversity during construction, as any flora and fauna within this area is likely to be eradicated due to movement of land, blasting and taking away the current small green "islands". However, during the operational phase, there may be long term adverse effects as a conflict of goals might arise. The implementation of green areas to accommodate biodiversity in the city could be hindered if the species that are meant to live here are negatively affected by the increase in artificial light and emissions. The question arises if the strengthening of relevant biodiversity will be accomplished if the design of the ecological conditions is first and foremost adapted to the polluted surroundings; What species will thrive and survive in the city? Are these the species we need to aid and promote?

Air Quality

During construction, it is inevitable that the air quality will be adversely affected. Within this phase, the main sources of pollutants are likely to come from heavy machinery. Some activities whereby heavy machinery is involved in construction that produces pollutants are land clearing, operation of diesel engines, demolishing existing buildings, road construction, residential construction, burning, and working with toxic materials all of which are expected to be done within Phase 3-4. The pollutants that these activities produce ranges from particulate matter (PM_{10}), diesel particulate matter (DPM), carbon monoxide, hydrocarbons, nitrogen oxides, and carbon dioxide (USEPA, 2019a). PM_{10} and DPM affect the environment in many ways, for example, it impairs visibility and also contributes to global warming (Brignon, 2003.) Because of the nature of the construction on Phase 3-4, visibility impairment which may result from plumes of dust particles could in the short term affect the air quality and contribute to the overall air quality in a negative sense.

Volatile organic compounds (VOC's) that are released from using oils, glues, thinners, paints, treated woods, plastics, and other hazardous chemicals that are widely used on construction sites, are also contributors to air pollution from construction sites and are considered to have a short-term low potential impact on the outdoor air quality (USEPA, 2019b).
In conclusion, it is assumed that because of the nature and size of the construction aspect of Phase 3-4, the magnitude of these impacts is categorized as somewhat having a minor adverse effect within the geographical boundaries for the phase.

During the operational phase, Phase 3-4 within its geographical boundaries will provide major opportunities with regards to housing. According to

Huddinge kommun, 2019a it is expected that this section will provide homes for about 3 000 people. With a growing population, there will be an increase in traffic in the area which can potentially lead to traffic congestion. Tyréns (2019d) conducted a study on the average amount of cars utilizing Huddingevägen in 2017. Results showed that an average of 18 600 cars was traveling along Huddingevägen per day. In addition, predictions were made concluding that given the new development and increase in population in the future, an increase to approximately 30 000 cars per day is expected. This would inevitably affect the air quality as such making this impact a major adverse effect (Chang et al., 2018). The major source of effect on the air quality in this section is expected to be the traffic traversing smaller roads within the residences area and also to larger extent traffic on the boulevard which is expected to transport the majority of the traffic. Traffic-related air pollutants are emitted by cars, trucks, buses, and "non-road" equipment (e.g., recreational vehicles or lawn equipment). Traffic-related air pollution contributes significantly to outdoor air pollution, especially in urban settings (USEPA, 2019a). Traffic emissions consist of different types of substances such as carbon dioxide (CO_2) particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs) (Zakaria et al., 2019).

While an increase in traffic will affect the air quality, plans are made by the Municipality to incorporate green spaces within the development of Phase 3-4. There will be two parks, residential buildings will be equipped with green roof and all streets connected to this area will have trees planted along roadways. This is a major beneficial effect since creating an urban district with large spaces of green area is known to improve air quality. Studies have shown that green spaces have a positive impact on air quality since it contributes to the removal of air pollution and carbon sequestration (Konijnendijk et al., 2013). Air pollution is decreased as green spaces intercept atmospheric particles and absorb different gaseous pollutants, (Yin et al., 2011). Green spaces sequester and store carbon within trees and other kinds of vegetation (Davies et al, 2011). This action by the trees act as carbon sinks and to a greater extent affect climate change by reducing CO_2 (Paoletti et al., 2011).

Surface water

During the construction phase of Phase 3-4 of roads, trams and buildings will have an overall negative effect on the surface water quality and runoff. The use of heavy machinery will cause compaction of the existing soil and lower the soil permeability rate, thus leading to more surface water gathering on the upper layer from precipitation and runoff from neighboring phases located to the south which will lead to more surface water transportation through Phase 3-4, and increase the flood risk (Bryant et al., 2007). The operation of heavy machinery will also have a harmful effect on the quality of surface water due to emissions such as particles from the tires, greenhouse gases and possible spillage of fossil fuels.

Due to Phase 3-4 being the home for several industries, the soil is believed to be mildly to highly contaminated from years of accumulation of pollutants such as heavy metals (Tyréns, 2019c). Excavation and displacement of contaminated soil could lead to the degradation of the surface water quality in the area by exposing the contaminated soil to atmospheric elements which in turn conjoin the sedentary pollutants in the soil with the surface water. Phase 3-4 consists mainly of hard surfaces such as asphalt and roofs. These hard surfaces have a high runoff coefficient that aids the transportation of surface water. Excavation of these paved areas could cause longer travel time for surface water, leading to higher flood risk during construction (Thomas, 2017). The excavation and removal of soil

could create low points in the area. it is not known if these low points would be able to manage runoff from the developed Phases 1 and 2 that travels through Phase 3-4, or be a possible gathering point for surface water. The demolition of older buildings, developed with outdated and degraded materials which contain harmful pollutants could increase the particulate matter in the water (Huddinge kommun, 2019a).

During the operational phase buildings will be equipped with green roofs to combat the heavy inflow of precipitation and decrease the risk of flooding. Surface water from the nearby phases located to the south will traverse through Phase 3-4, thus making it one of the most sensitive areas in the project site due to it being the centre for several residential areas and schools (see Figure 34) (Huddinge kommun, 2019a). Paved roads will be equipped with modern stormwater systems that will combat the heavy inflow of runoff, leading to an improved flow of surface water compared to the present time (Huddinge kommun, 2019a). The use of the roads by vehicles such as cars, busses, and trams could have a negative effect on surface water quality. Residual particles from the tires and rails will be become airborne and accumulate in the surface water which will lower the quality (Cadle et al, 1979). More green areas will be developed which will dampen the surface water transportation as the parks will work as a buffer, regulating the transportation of runoff before it is transported to the wetlands. It will also work as a natural filtration centre for surface water. The parks will also be beneficial in a flooding scenario as it will be strategically placed at a topographical low point and become a gathering area for water during heavy rainfall (Huddinge kommun, 2019a). An overall calculation shows that through the modern stormwater assessments, a decrease by 30-90 % of particle pollution matter in the surface water is expected depending on the substance of the pollutants (Huddinge kommun, 2019a).



Figure 34. *Blue arrows show the overall flow of surface water during the operational phase is in a north-east direction through Phase 3-4. The blue spots are the planned parks which will be a gathering point for surface water. (Adapted from Huddinge kommun, 2019a).*

Groundwater

The groundwater could be affected in numerous ways during the construction of Flemingsbergsdalen. Since the groundwater level is at a shallow depth, this could cause implications in the developing process. Especially if buildings are equipped with basements, garages or other facilities below ground. The groundwater table will have to be lowered by draining the groundwater or transporting it away. To follow-through with this process, a permit needs to be given and be approved by the

environmental court (Huddinge kommun, 2019a). If this plan takes action it could lead to the risk of subsidence of the ground and the destruction of buildings due to the instability of the ground (Galloway et al., 2011).

Since the groundwater table is close to the surface, the risk of polluting the surface water which in turn will permeate down to the groundwater during the construction with heavy machinery is relatively high. Phase 3-4 consists mainly of clay and till type soil. Percolation is believed to be minor in clay regions due to the very low permeability rate of the soil, but it is likely to occur in areas where the soil consists of till, leading to a higher risk of groundwater contamination (Structor, 2019). With insufficient data of the groundwater state at the present time, no real prediction of the true effect can be assessed. Although assumptions based on present pollutants in the area, it is assumed that the impact of emissions from heavy machinery on the groundwater is to be of a minor adverse.

The excavation and movement of land would most likely disrupt the shallow groundwater flow in Phase 3-4 and decrease the groundwater supply to the receptors. Demolition of the bedrock could risk additional pollutants affecting the groundwater if the bedrock is sulfide-rich, and weathering is achieved by the blasting of the bedrock, leading to the potential acidification of the soil and groundwater (Hindar et al., 1994). Further studies of the bedrock need to be assessed in order to definitively say this would have a real effect on the area.

During the operational phase, the permeability of the area is expected to increase along with the increased areas of green spaces, after the development of two large parks. The parks would have a positive effect on the groundwater reservoir through the increase of groundwater supply from precipitation and runoff. However, this could also lead to a higher risk of pollutant particles from traffic which are carried by surface water which would then permeate into the soil, and possibly affect the groundwater storage. Overall, it is most likely the parks would have a positive effect on the status of the groundwater, since the intended purpose for the park besides recreation is to filter the surface water carrying these particles before its either transported away or permeate down to the groundwater, giving the operation of green spaces a beneficial role in the quality of groundwater (Huddinge kommun, 2019a).

Noise

According to the Swedish Environmental Protection Agency (Naturvårdsverket, 2019c), noise is defined as “unwanted or disturbing sound. Sound becomes unwanted when it either interferes with normal activities such as sleeping, conversation or disrupts or diminishes one’s quality of life”. With Southern Stockholm’s growing development to urbanization, noise is an environmental concern and a continuing nuisance. The major contributor to environmental noise in Sweden comes from traffic, railways, and aircraft, however, noise from neighbors, construction sites (considering that it is a short-term impact) contributes little to the overall noise for a specific area (Eriksson et al.,2013).

Existing Standards and Guidelines

Noise impact emanating from construction and operation activities will be assessed against the standards of the Naturvårdsverkets, as seen in Table 1 and Table 2 in Appendix 3.

Noise from traffic to and from the construction site should be assessed according to the traffic noise guidelines. But traffic within the construction site is counted as construction noise (Naturvårdsverkets, 2019d). Potential noise sources from the construction phase are assumed as follows:

1. Working construction equipment

   The activities during the construction would involve demolition of existing buildings, use of heavy machinery, pavement of roads, piling and excavation. The equipment likely to be used for the construction phase is as follows: Bulldozers, excavators, dump trucks, forklifts, road roller, crane, concrete batching plant, motor graders, etc.

2. Traffic - Material Supply

   There will be a considerable amount of traffic during the construction phase. Equipment transport of asphalt, building materials, workers to and from the construction site.

3. Blasting

   Blasting may be used depending on the depth needed to establish the foundation for the residential building, offices, and schools.
   Blasting can cause existing buildings to vibrate causing damage to the physical structure of the buildings.

The noise level is expected to increase during this period. Considering the spatial boundaries of the project area, numerous aspects that will have an impact on the noise in the environment. Because of the potential sources of noise, there is expected to be short term effects on the environment lasting for the period of the construction cycle. However, considering the noise level from each equipment working at the same time when standing 50ft away, for example, concrete mixer truck is at 85 dBA, compactor at 80 dBA, and crane mobile at 83 dBA noise levels are expected to surpass the required noise guidelines for construction activities as seen in Table 1 in Appendix 3 **(**Federal Highway Administration, 2018).

In general, increased levels of sound emanating from the use of heavy construction equipment ranges from 80 to 120 dBA while power tools commonly used in construction can create sound levels up to 115 dBA (Centre for Diseases control, 2019).

These potential noise sources are expected to have minor adverse effects on surrounding areas and in particular the noise receptors since it is expected that these sections will be built then occupied when phase Phase 3 is in the construction phase.

During the construction stage, vibration is expected to be a product of blasting and construction equipment. Equipment or activities used in construction can be categorized as continuous vibrations and single-impact (transient) or low-rate repeated impact vibration, according to the type of vibrations and/or activities occurring in each category (California Department of Transportation, 2013). Some examples of continuous vibrations are excavation equipment and vibratory compaction equipment, all of which are expected to be used during the construction of Phase 3-4. Blasting and impact pile drivers are examples of single-impact (transient) or low-rate repeated impact vibration and also is expected to be used in the construction phase.

In the year 2030, when the project is expected to be completed, the population is expected to be approximately 122 000 to 150 000 (Huddinge kommun, 2014). The majority of the population will be residing within Phase 3-4 since it is an area that has the largest residences.

During the operation phase, an increase in population growth and the establishment of Flemingsbergsdalen is expected to attract many businesses and people from all walks of life. Commercial and public

facilities within Phase 3-4 will be established on the first floor of the residential buildings (Huddinge kommun, 2019a) to meet the needs of the people of Flemingsbergs Dalen. Because of the increase in activities in this area noise levels would inevitably increase and surpass the current level as assessed by Tyréns (2019c) making this aspect a minor adverse effect on the noise level in the environment.

As traffic increases given that there are no technological advancements in the operation of vehicles that produces less sound than today, it is expected that there will be an increase in noise in the newly developed phase. A noise assessment carried out by Tyréns (2019c) showed that noise levels in the area range from 55-75 dBA. In the vicinity of the boulevard, sound levels were recorded at 55-65 dBA. In areas closer to the railway and Huddingevägen sound levels range from 70-75 dBA (Figure 6). The values in this area are currently high and exceed the guideline values as stated in Table 2 in Appendix 3, furthermore, it is expected that with an increase in road and railway traffic, noise levels will exceed during the operation phase of Phase 3-4, as such this can be characterized as a major adverse effect on the noise levels in the environment. On a positive note, green spaces in the area can act as noise barriers and help decrease the sound levels.

Soil

As construction is underway, minor adverse impact can degrade the soil quality status. Compaction of soil as heavy machinery operates on the topsoil is most likely to occur. The likelihood of erosion by the use of heavy machinery and the vibration that originates from a construction site would increase in areas where the soil consists of clay (Tyrens 2019a). In 1960 and -70s, the area was used for agricultural activities. After the development of factories, the soil in Phase 3-4 has been polluted with numerous different contaminants such as heavy metals and organic solvents (Tyréns, 2019a). The excavation of the soil could increase the displacement of the existing soil contaminants to other surrounding areas with the help of surface water.

Due to it being a relatively polluted soil at the moment, emissions from the use of heavy machinery would have a minor adverse impact on the already spoiled soil, by only further degrading the soil quality. The two main soil types located in Phase 3-4 are clay and till. Till has a higher hydraulic conductivity than clay, therefore transportation of groundwater and the spreading of contamination is recorded at a higher rate in areas consisting of till (Langston et al, 2013). Further contamination within the till area should be cautioned to not accumulate more contaminants and transportation to recipients. In Phase 3-4 there are several visible bedrocks. Due to its already sensitive soil, the possibility of blasting of bedrock needs to proceed with caution to not increase the acidification of the soil (Hindar et al., 1994).

For the main part of the operational phase, the soil will not experience further adverse impacts from the operation of the different facilities in the area. Due to an increase of green spaces, the permeability rate of the area will increase, possible contamination from vehicles could contaminate the soil, which will most likely happen in the two planned parks in Phase 3-4. The parks as previously stated will be a gathering point for contaminated surface water from the neighboring phases in the south leading to surface water permeating the soil and further possible contamination from the increased traffic. The main purpose of the parks besides being a recreational area is to filter surface water and accumulate contaminants. This will not only negatively affect the state and health of the soil but the people who visit the parks and the children who play in the soil.

3.1.3.2 Cultural Environment

Cultural Heritage

In accordance with the cultural heritage code SFS2013:548, under the section of cultural historic artifact SFS2013:548 §1, any object that falls under this section is protected by law. Sofia Gregorsson at Huddinge Municipality has stated that an archeological survey of the area will be conducted (Gregorsson, 2019. Personal correspondence).

Phase 3-4 is suspected of holding a historic artifact (Lantmäteriet, 2019). Depending on the type of historic artefact, it may be susceptible to various strains. During the construction phase, it may face detrimental physical damage during the blasting and construction of roads. Depending on how well preserved the artefact is today, any emissions from the construction phase have a potential effect on the artefact once it is exposed. The same is for different physical and chemical circumstances during operational phases, such as acidic rain, traffic emissions, and vandalism, which may also affect the artefact. If the site is excavated, it will have to be suitably protected during construction and preserved during the operation of the area (Isaksson S., 2019. Personal correspondence). In addition, on the basis of SFS 2013:548 §2, there should be a designated area of the appropriate size, to accommodate the preservation of the artefact. According to the present layout of Phase 3-4, this potential artefact is not accounted for, nor has a designated area been reserved.

Visual Landscape

Despite the visual value of the current site of Phase 3-4 being low, the perception of the area might be affected negatively during the first stages of the project, namely demolition and construction. Both within and outside the construction site, the visual landscape will be significantly altered, and after the construction is completed and operation commences, the visual landscape will change once again. The design of the project proposes a modern residential area, rich in vegetation, parks and green rooftops which contributes to a positive perception of the area. However, the building plan suggests closely located buildings, accomplishing an “urban feeling”, but might result in a sense of being enclosed, and essentially hiding the greenery. Additionally, the new buildings will be higher and have a more distinguished influence on the setting. Despite its scarcity, the vegetation today is highly visible due to the spacious spread of buildings, and that they are relatively anonymous, albeit visually dissatisfactory.

As compared to existing roads, the planned project suggests vegetated ditches and tree-lined avenues, incorporating roads into the green visually appealing design. Despite the beautification of the transport infrastructure, traffic could potentially increase in the area, as the area receives more residences and activities connected to the stores. The new boulevard, which is a development of the current Regulatorvägen, will act as the main road, hosting trams, roads, and walking paths. This expansion could potentially disturb the visual landscape for adjacent buildings, compared to how Regulatorvägen is used today.

Additionally, the project is planned to be constructed during the period 2020-2040/2050 (Gregorsson, 2019. Personal correspondence). Even if this impact is classified as short term, since the visual disturbance will end once construction is over, the project will be carried out during a longer period of time, and tenants which have moved in during the completion of the first phases will have to experience these disturbances for the remaining time.

3.1.3.3 Socio-Economic Environment

Housing

During the operational phase of Phase 3-4, effects from the impacts on housing can range from negative to positive and affect new and old residents in Flemingsbergsdalen. Given the general lack of housing in Sweden and in particular Flemingsbergsdalen, new housing has a positively high potential of being a welcomed opportunity for newcomers since they would be attracted to the quality of life offered within the city (Boverket, 2016). On the other hand, some local residents may have some concerns about their already existing residences.

In London Barker K. (2003) conducted a review of Housing Supply whereby they looked at the difficulties involved in the planning system when a balance is needed between economic, social and environmental objectives at the local level. The study examines the further cost of local development and the perception of the local residents who are affected. Results showed that potential benefits for the residents leaned towards diffusing or getting lost during plans rather than being transparent. Hence, it can be concluded that the Municipality may focus on the positive impacts of this development rather than the small negative impacts and still go ahead with the proposed plan. This may be a potential situation for current residents in Flemingsbergsdalen. Some people may feel that their concerns about the effects they might experience may be easily ignored in the system since generally on the large scale the current development may focus on the greater good. Some potential negative impacts residents can experience when new residential and commercial buildings, and parks are established can range from congestion, pollution, safety (crime and traffic), fancy high tech development considered as ill-designed because it failed to foster a sense of community and target integration of the old and new population and existing home prices may be lowered thus causing the wellbeing and sense of pride of the current residents to reduce (Whitehead et al., 2015).

The cost of living in urban areas is another factor which is considered to be very important. According to SCBs (2019) article about higher rents in newly constructed rental dwellings in 2018, rents were 2.2 % higher in newly built rental apartments in 2018 when compared to the previous year. SCB also did a trend analysis of annual rents/ charges per dwelling in Sweden and it showed that there has been a constant increase in rents from the year 1991-2018. With the newly built apartments, offices etc, in Phase 3-4 it can be concluded that this trend will likely continue in the future. A good reason for this is the developers cost for building these structures. The cost of building material is high in Sweden, as such the developer compensates for this in the price setting for the apartments. However, Flemingsbergsdalen's plan program proposes to build green buildings. Common perceptions of people may be that because the buildings are built sustainably, the cost may be high. Would the lower cost of the lifecycle of the building offset the cost of constructing the building? If so, how?

Constructing green buildings can be beneficial to the owners in several ways. According to (Benson, 2004), sustainable designed buildings are beneficial in the sense that it provides cost savings from the lifecycle of the building, the individual that owns the building is very productive and have better health and the prestige of owning the building induces a sense of pride.

Life cycle savings from the building can be characterised as reduced utility costs and maintenance savings (Nalewaik, et al., 2010). As energy increases,

people would like to reduce their utility bills to avoid paying the inflation, so they opt for better systems in their buildings and also try to maintain their maintenance schedule to avoid paying the extra cost for repairing. There is data to support this whereby one company in the first year of operation at their headquarters "…used 42 % less energy and 34 % less water than standard buildings of comparable size" (Lockwood, C., 2006).

Design plays a very important role in the construction of green buildings. Green buildings design can focus on improving the quality of the environment within the building such as the installation of technology to produce a higher air quality, the temperature just to name a few. While green buildings may provide life cycle savings, according to (Benson, 2004) improvements in human performance are associated with sustainably designed buildings. (Koga et al., 2008) concluded that people residing in green buildings had good health and comfort as toxic and harmful substances were absent within these buildings while in education facilities, student's retention and learning ability may improve and in offices, worker's productivity may increase.

While some people may feel dissatisfied, the positive effects of urbanisation cannot be ignored. The plan program emphasises a green sustainable environment with parks and vegetation and properties that are built with environmentally friendly material which is architecturally structured in a way to the benefit of the environment (Huddinge kommun, 2019a). In addition, other potential impacts may range from providing better homes with larger spaces to accommodate families, an increase in the value of the property if the new development complements existing homes with new roads, local shops, restaurants, etc (Whitehead et al., 2015).

Considering both the negative and positive impacts, it can be concluded that because of the current state of Flemingsbergsdalen, a sustainable development supporting housing outweighs the current situation, as such the effect of the development of housing within Phase 3-4 will have a major beneficial impact on the socio-economic environment in Flemingsbergsdalen.

Recreation

Most of the area under Phase 3-4 is covered by industries thus there is no or very low green space available at the moment, and due to that, any impact on the green space during construction is not applicable. However, there will be a direct minor adverse impact on the existing library (Arbetarrörelsens archive and library) as it will be demolished and removed during construction (Avatare Kemmlert, 2019. Personal correspondence). Demolition and construction activities are expected to produce huge waste material, and if that is not handled properly e.g. dumped on the site reserved for green space, it could have adverse impacts due to contamination of the area.

Commercial and residential buildings may have recreational centres such as gyms, cafes, and shops which will increase the availability of recreational activities. Residential areas will contain a courtyard and be a walking distance from parks. Stadsdelparken is expected to be the largest in the area. These parks can provide an attractive living environment and a natural meeting point in the area. Urban green spaces serve as a source for relaxation and provide emotional warmth (Haq, 2011).

According to the project description, the boulevard will have lush green sides which will contribute towards an attractive and pleasant environment. Study shows that exposure to urban nature along with urban built

environments improved multiple measures of cognitive function and development, including attentional capacity and memory. It also states that perceptions of greenery improvements were associated with a decrease in depressive symptoms among adults (Kondo et al., 2018). Three primary schools and one elementary school will induce recreational activities among children. It will provide an opportunity to develop their cognitive, and mental abilities. It is assumed that the event building will be used for social gatherings, functions, and events, etc which will help people to come closer to their neighbourhood and will boost the sense of safety among people. The courtyards which will be enclosed by residential buildings are expected to have a play area for kids, work as a gathering point. Littering is of concern by the people utilizing the recreational areas and consequently would have an adverse impact on the general aesthetics and ecological status of the area. Dust, emissions, and noise from traffic can have a negative impact on the recreational area and therefore influence the feelings and perceptions of the residents and workers. Traffic-related environmental exposures including increases in air pollution, noise and temperature levels, as well as reductions in green space (Kheris et al., 2016)

Health

Construction of a building or road are associated with land clearing, ground digging, cut and fill operations (Kumar et al., 2012). To fulfill these tasks, mobile machinery, hand tools, and heavy machinery is used, however, various studies found that longer exposure to vibrations generated by these machineries could have negative health effects on workers such as vibration exposure (Donati, 2008). The existing structure for Phase 3-4 is already contaminated with heavy metals and during demolition, workers might be exposed to these metals. Several studies have shown that toxic metals exposure causes long term health problems in humans. In addition to that, the dust and other pollutants generated from demolition and construction could also have a direct major adverse impact on the health of people working there (Bergdahl et al., 2004). The noise produced by machinery, blasting, and excavation, etc is one of the most highly found physical contaminants in the construction sector. The effects due to noise exposure have a very important influence on people's health and well-being which may produce temporary or permanent hearing loss (Fernandez et al., 2009).

Compared to the present conditions, there will be more green space, and the major advantage of this will be an improvement in the physical and psychological health of the people living in the area. "The urban brain" study written by (Aspinall et al., 2015), found that people have more positive emotions when navigating through urban green spaces compared to urban spaces that lack green areas. It is assumed that the presence of commercial buildings in the nearby area will provide more opportunities for people to find work in their close vicinity and thus reductions in self-reported absenteeism and affected work hours as a result. The employees may experience a positive effect on their new work environment and on their productivity. It is expected that native residence may feel less stress due to shorter commute time.

People spend most of their time indoors, at home or work; health problems could either be directly or indirectly related to the building itself, because of the construction material that is used, or the size or design of the individual dwellings (Bonnefoy, 2007). Commercial buildings, on the contrary, are also likely to attract workers from outside the area, which could lead to traffic-related exposures like air pollution, greenhouse gases, and noise. Noise is likely to induce poor sleep quality and bad mood on residents living close to shops and roads (Eberhardt, 1988). Thus, there

could be major beneficial impacts on health regarding residential and commercial buildings but minor adverse impacts due to traffic emissions. Impacts on health due to waste generation and sealed space are not assessed.

Safety

Construction work is often heavy and extracts a heavy toll on the body. The risks of accidents and occupational injuries are common among construction workers (Arbetsmiljöverket, 1999). It could happen due to lifting heavy objects, unsuitable work conditions, accidents caused by heavy objects, falling from great heights, or any machine injury. In the process of blasting, demolition, and construction, injuries can occur. Demolition of the existing structure should be estimated as precisely as possible, otherwise, it could fall in any random manner and cause injury during the demolition phase. During blasting, it is indeed important to estimate the impact of the flying objects. Schneider (1995) stated that a flying rock could travel beyond an inadequately defined blast area and cause injury. The two power lines (120 and 70 kV) that intersect the Phase 3-4 could pose the risk of being electrocuted as they are positioned overhead. Heavy equipment like bulldozers, excavators, forklifts, cranes, etc are among the main causes of the accidental contacts (Construction safety council, 1996). During construction, most of the roads will either be blocked or closed partially. Thus, the area could be prone to accidents due to decreased availability for general traffic, as well as construction vehicles interacting with the general traffic. Poor planning and development deadlines also increase the risk of accidents. The exact process of construction is not yet known, however, it is expected that the Swedish work environment regulations will be followed to minimize the risk of accidents and increase the safety for the construction workers.

It is expected that the updated Swedish Fire Protection Association (Brandskyddsföreningen) fire and safety hazard laws and regulations will be followed during construction, it is safe to assume that all buildings will be less prone to fire and also equipped with all necessary fire equipment. As more people will start to move in, the increase in traffic could pose a minor risk to safety however dense urban areas are considered safer due to roads having lower speed limits compared to open and spatial areas which decrease the chance of accidents. “Dense urban areas, less-“forgiving” design treatments—such as narrow lanes, traffic-calming measures, and street trees close to the roadway—appear to enhance a roadway's safety performance when compared to more conventional roadway designs” (Ewing and Dumbaugh, 2009).

The project aim is to make Phase 3-4 more lively and safe as compared to the present day scenario. Present-day Flemingbergs have a rather high crime rate, it is expected that after the construction, the area might continue to be used by such anti-social elements to conduct their activities like drug paddling, mugging, stealing, etc. This can increase the fear and insecurity among the residents. However, with the rise in population, these risks will be reduced as active neighborhoods will increase the feeling of social security and safety among residents. According to the “Eyes on the street” theory, the presence of people and varied activities leads to an increased feeling of safety and a reduction in the fear of crime (Wekerle, 2000). The area is also expected to generate a large amount of employment. With the working population, it is proposed that people will be less likely to indulge in criminal activities and thus make the area safer. As compared to the present situation Phase 3-4 will consist of more parks and green space. The development of new green areas would have a direct beneficial impact on people's perceptions of safety and their willingness to use a space.

National park and recreation foundation research shows that there is a connection between park and recreation use and safety: where people use parks in a positive way and in substantial numbers, which will lead to all people feel more secure.

Equality

The impact the construction stage has on equality in Flemingsberg is of minor importance due to the fact that options to counteract segregation and exclusion are limited. However, during the time of construction, a minor negative impact can be detected on the current English school within Phase 3-4. Because of the construction work, the operation of the English school will be disrupted and suspended, which could lead to a preliminary relocation of the school or the dislocation or transfer of the school children to other schools. As the potential relocation could not be fully confirmed by the Municipality, this impact needs to be addressed at a later stage.
As regards the current buildings and their demolition, the Municipality service in Huddinge has assured that the landowners would be compensated and a relocation possibility for the companies will be provided in the Municipality of Länna (Huddinge kommun 2019i. Personal correspondence).

During the operational phase, a variety of sectors will be affected in connection to changes in equality. These aspects need to be pointed out separately:

Housing and Employment: Around 50 % of Flemingsbergs inhabitants have a migrant background and were born outside of Sweden (Huddinge kommun, 2016). Many young immigrants and households with low-income can be found in less attractive rental housing (Andersson, 2007; Boverket, 2016). High housing prices and the fact that newly constructed and existing dwellings are not equally affordable, which could affect some groups, such as low-income households and young adults more negatively than others (Boverket, 2016). Moreover, as immigrants are facing restricted access to the labour market, they are therefore experiencing a lower level of income, and as a consequence, the acquisition of homeownership is difficult (Andersson, 2007). These factors contribute to the development of spatial segregation, unequal opportunities and overall disparate access to the housing and labour market. Therefore, the affordability of housing can have a major impact on equal access opportunities to the housing market. The developers of the suggested project are thus urged to consider the suitability of the houses in order to meet the needs of different social groups and to avoid gentrification and the consequential marginalization and displacement. Under the assumption that these concerns will be taken into account and addressed in a suitable way, the project can add a significant beneficial momentum to the housing market through providing new residential areas for various socioeconomic groups (elderly, young adults and families, students, migrants, etc.) and thus increase equality for all members of society in southern Stockholm.

Public and Commercial Facilities: The effect of open, accessible facilities, such as the (pre)schools or the event and culture centre and other open, public meeting spaces (for example parks) in Phase 3-4 can promote and facilitate diversity, forward the building of personal networks and enhance social inclusion. Social participation and neighborhood commitment can be strengthened and long-term benefits can arise due to "*(...) the influx of human capital the reinforcement of innovative and entrepreneurial capacity, cultural enrichment, increased supply of less expensive services, etc.*" (Börjeson, 2018). On the other hand, increased competition for smaller stores in Phase 3-4 from larger chain stores in adjacent phases can lead to constraints for small shopkeepers. It is yet to be determined the

range and type of businesses that will move into the buildings in Phase 3-4. Yet, commercial buildings, such as cafés, restaurants, and shops can contribute to integration, diversity, and inclusion, as they act as meeting points and provide space for exchange of views and ideas.

Public Transport: The planned public transport in Phase 3-4 will have a minor to major beneficial impact on equality, because of new transport possibilities and pathways for cyclists and pedestrian walkways, a tram, and car access. If planned properly - broad pathways and safe pedestrian walkways with integrated guide systems for the visually impaired and features for the functionally disabled - will add a beneficial feature to disadvantaged people and people with special needs, and thus enhance the equality of mobility. According to the Public Transportation Act (Sveriges Riksdag, 2015), all members of society must be able to work, study and take part in community activities on equal terms and thus access to a public transport system must be ensured.

Employment

Currently, Stockholm region provides a growing knowledge-intensive service industry (City Planning Administration, 2018). As Sweden is shifting towards high-qualification jobs and a high-skilled economy, workplaces in the branches of the information and communication technologies are in high demand (ibid.). The fastest-growing branches in Huddinge are as of today retail, construction, business services, logistics and transport and IT as well as telecommunications (Huddinge kommun, 2019g). Huddinge Municipality has unemployment rates of around 6.5 %, just 0.5 percentage points below the Swedish median (Carlgren, 2018).

Around 26 % of Huddinge's unemployed inhabitants reside in Flemingsberg (Huddinge kommun, 2019h). The fact that around 73 % of Huddinge's inhabitants (as of 2017) work in other municipalities (Huddinge kommun, 2018) can be related to the general problem the Stockholm region is facing: many jobs are unevenly distributed within the region. Along with the Vision 2040, every Municipality should aim at providing housing, jobs, and services, so that a balanced distribution of attractive workplaces can be ensured (City Planning Administration, 2018).

During the construction stage, a number of short-term job opportunities arrive, as workers of various types of jobs are needed. These include builders or general contractors (bricklayers, carpenters, engineers, ground workers, plasterers, plumbers, etc.), and also building inspectors, site managers, as well as architects, designers, and several subcontractors.

As Sweden is facing the problem of segregation, due to the high unemployment rates of immigrants, the country is focusing on social sustainability and social procurement (Petersen and Kadefors, 2016). According to Petersen and Kadefors, Sweden is experiencing a shortage of construction workers (ibid.). There is a high demand for this particular workforce, especially as the construction industry will experience an increase in the upcoming years (ibid.). Construction projects can therefore act as vehicles for societal changes and provide employment opportunities for disadvantaged groups. Furthermore, it is suggested that the construction work should include the training and recruitment of local workers, in order to increase employment and work opportunities.

With the new development in Flemingsbergsdalen, up to 35 000 workplaces will be created (Huddinge kommun, 2019a). The kind of companies and businesses that will settle into the offices is yet not decided. Phase 3-4 includes preschools, a school, several office buildings and an event and culture building, which can potentially contribute to the creation

of long-term jobs. Four office buildings and four mixed-use buildings, which account for approximately 30 % of all office buildings in the area, will be built during this stage and will provide a number of long-term job opportunities.

In line with the objectives for the East Mid- Sweden program, investments into regional growth and employment are to be based on development strategies, which should aim at contributing to beneficial environments for entrepreneurs, economic development and innovation (Swedish Agency for Economic and Regional Growth, 2016). The region's growth in SMEs (small and medium-sized enterprises) is an important overarching aim of the country (ibid.) and will be incorporated in the proposed project in Flemingsbergsdalen. A large part of the new office buildings in Phase 3-4 will be available to SMEs, which is why commercial buildings will have a major beneficial effect on employment.

Nevertheless, as opportunities for people with lower qualifications will be in the background in the forthcoming years, the long-term and stable job opportunities arriving with this new development should be studied more in-depth. The question of "who will benefit" from the creation of these workplaces and if the new offices can counteract the present situation in Huddinge is yet unanswered. Will the development contribute to providing job opportunities for the people currently living in Huddinge? What kind of jobs will be created and which members of society are given access to the created workplaces is of crucial importance.

The operation stage will provide the area with new offices, thus a ground upon which start-ups and small enterprises can flourish, with a vision of up to 35 000 employed people in Flemingsbergsdalen. The rather short-term employment possibilities throughout the construction phase will be of minor importance but added to the long-term job opportunities that will arrive with the new business and offices, public facilities and new transport means, this program aims at a high employment rate in the area.

It is therefore argued that the overall finalisation of the development and the construction of new public facilities and offices in Phase 3-4 will contribute to providing new employment opportunities and will thus have a major beneficial impact on the socio-economic environment in the southern region of Stockholm, under the assumption that accessibility is provided in equal terms, (either through adjusted rents or subsidies). Challenges that may reside are related to providing long-term jobs for disadvantaged people and long-term unemployed, as well as people with a lower education background.

Accessibility and Connectivity

As was mentioned in the Introduction, Flemingsberg is already an important junction, including commuter, regional and long-distance trains. In the long term, one of the aims of the project is to connect Flemingsbergsdalen to the rest of Flemingsberg (Huddinge kommun, 2019a). As new offices and houses will be built, it is of additional importance to ensure the connectivity to the city centre and decrease commuting times.

Part of the vision is for fast trains to be able to stop at Flemingsberg and connect Skavsta in the south with Arlanda in the north. As of today, the transport network lacks links. A cohesive transport system is of importance (Tyréns, 2019d). Projections for travel and public transport show that journeys within the Stockholm region will increase, on the one hand as a result of the increase in population and on the other hand because of an increase in the standard of living (The City of Stockholm Traffic

Administration, 2012). Trips by car are expected to increase slightly faster than travel by public transport (ibid.). Thus, the project will aim at connecting different regions and the regional city centres to ease the access for commuters, tourists and everyday journeys, but by emphasising sustainable travelling.

However, the increased connectivity within Flemingsberg should be prioritized. The overall goal is to foster mobility and accessibility by foot, bicycle or public transport for a trip within and to or from Flemingsberg. By 2030 around 70 % of all trips in Flemingsberg can be made by foot, bicycle or public transport (Tyréns, 2019d). Although destinations can be reached more easily, accessibility to the regional city centre and within Flemingsberg by car will be provided, but not prioritized.

The main boulevard (Figure 35) will traverse the southern part of Phase 3-4. The boulevard, once finished, will provide the possibility to travel by public transport or cars. Bicycle and pedestrian pathways are also intended. During the construction stage, especially during the demolition of the current buildings and preparation work for the construction of the new buildings, minor to major short-term disruptions can be expected, as the roads will be partially blocked and predominantly used by trucks and construction workers. As the Regulatorvägen in Phases 3-4 is not a major thoroughfare today, these short-term impacts on accessibility during this time are of minor significance.

The benefits of the new road system during operation in terms of accessibility are various. In regard to the workplace possibilities that will be created, it is of great importance to provide corresponding means of public transport, not only for local residents and employees, but also for commuters from other municipalities. This will be provided via a new tram and busses that operate along the main boulevard, which is the southern main road of Phase 3-4 (Figure 35).



Figure 35. *Proposed street types and street hierarchy (Adapted from Tyréns, 2019d).*

From the perspective of the new offices and future enterprises, the concept of accessibility, fast connection and commuting in lesser time is also of great importance. It should be mentioned that the district's (and thus the new companies) access to a skilled workforce is also directly linked to high-quality education and good availability of housing (City Planning Authority, 2018). The access to adequate housing and living space along with affordable rental prices are a prerequisite for a thriving urban development.

Therefore, accessibility not only refers to the use and means of transport and the ease of reaching a destination (Deboosere et al., 2018), but it also accounts for the access to public services, housing, and jobs. Planners must address accessibility in order to "...enable as many as possible to participate in society on equal terms" (Boverket, 2019). In order to ensure equal opportunities (especially for people with disabilities and special needs, lower-income, elderly and children, etc.) the access to public services, leisure activities (including parks and sports facilities, which will be located in Phases 3-4), schools, community buildings, and assembly places, as well as proximity to shops and workplaces are of crucial importance.

New developments need to take on this responsibility and municipalities need to highlight educational and social services for every member of the society to enhance social well-being, support integration and avoid exclusion (Sweden.se, 2019). The project outlines the construction of new preschools and schools within Phases 3-4, thereby opening up the opportunity for young families to move into Flemingsberg. Additionally, a large event and culture-building will be integrated into the district, thus culture, community, and identity building are considered.

As all factors are addressed in a preliminary sense, the significant impacts of the construction of public services and housing (under the premise of affordability) are major beneficial for society and align with overarching goals of the country. The impact of the planned development will thus have direct major beneficial effects on the social environment through improved living-conditions and accessibility to public services, transport, and workplaces.

As there are no detailed plans on the transport system, more in-depth studies are required to ensure accessibility to public services, workplaces and housing for disabled and other disadvantaged groups.

Table 8. *Impact matrix showing the assessed impact significance levels for the corresponding actions and indicators in Phases 3 and 4.*

		Construction Phase				Operation Phase						
	Actions / Environmental Indicators	Construction of infrastructure	Movement of land	Demolition of buildings and removal of infrastructure	Exploiting unused areas	Public facilities	Commercial buildings	Residential buildings	Waste generation	Sealed surfaces	Traffic	Parks and green spaces
Natural	Biodiversity	-	-		+ / -	-	-	-	-		-	+
Natural	Air (quality)	-	-	-	-						- -	+ +
Natural	Surface water	-	- -	-		+	+	+		+	- -	+ +
Natural	Ground water	-	- -								-	+
Natural	Noise	-	-	-	-	-	-				- -	+
Natural	Soil	-	- -								- -	- -
Cultural	Cultural heritage	- -	- -	- -	-						-	-
Cultural	Visual landscape	-	-	-	-	+	+	+		+	+ / -	+ +
Socio-Economic	Housing					+ +	+ +	+ +				
Socio-Economic	Recreation			-		+ +	+	+	-	-	-	+ +
Socio-Economic	Health	-	-	-	-	+ +	+ +	+ +			-	+ +
Socio-Economic	Safety	-	-	-	-	+	+	+		-	+	+
Socio-Economic	Equality			-		+ +	+	+ +			+	+
Socio-Economic	Employment	+	+	+		+	+ +					
Socio-Economic	Accessibility and Connectivity	-	-	-		+ +	+ +	+			+ +	+

3.1.4 Phase 5-6: Recreational Parks and Schools

3.1.4.1 Natural Environment

Biodiversity

The exploitation of presently unused areas in Phase 5-6 is mainly located in the forest area in Phase 5, where the plan is to deforest the entire area before the construction of a park and residential buildings (Huddinge kommun, 2019i). The exploitation of unused areas constitutes a major adverse and long-term effect on biodiversity, where all vegetation, animals and the soil with its organisms will be removed. Since the forest area in Phase 5 is part of the larger natural area called Hanvedenkilen, deforestation would contribute to habitat nibbling, which could become a cumulative impact if more projects are planned and built at the expense of Hanvedenkilen's natural area.

During the demolition of the current buildings and the construction of infrastructure, the noise level increases, affecting the nature negatively (major adverse), for further information see Subsection: *Noise* in this Chapter. The excavation of soil is predicted to have a major adverse impact on biodiversity, since the soil diversity is affected and the roots of vegetation are damaged or removed.

The baseline conditions of the green areas in Phase 5-6 is a forest with some to significant ecological value. The planned park is described as a hilly space with exposed natural bedrock and open grass areas (Huddinge kommun, 2019a). The construction of a park instead of conservation of the forest might have a significant effect on the biodiversity, depending on the value in the current state of the forest and the future state of the park. The design of the park determines if it will hold a smaller or larger amount of species, depending on the number of habitats and the level of disturbance (Ricklefs and Relyea, 2014). If the park will consist of a large mowed lawn and dispersed planted trees, biodiversity might be partially lost creating a minor adverse impact. But if the park is designed from an ecologically sustainable perspective, the biodiversity in the area may even increase which would create a minor beneficial impact. However, the red listed species associated with the forest might be lost, since red listed species often are related to specific habitats.

The planned buildings in Phase 5-6 are expected to contribute to creating light pollution (as mentioned in Section: 3.1.1.1 *Natural Environmental* subchapter *Biodiversity*), and the increasing number of inhabitants in Flemingsbergsdalen might have an impact on the biodiversity in the project area as well as on the nature reserve just outside the project boundaries. In the plan program, it is assumed the nature reserve will get more visitors, causing straining on the forest floor and disturbing the animals (Henriksson, 2019). Because of this, the impacts for public facilities and residential buildings are assessed to be minor adverse. Since there are no commercial buildings in Phase 5-6, this is assessed negligible.

The expected increase of traffic in the area has a minor negative impact on biodiversity, because of increasing noise from the traffic (see Subsection: *Noise* in this Chapter), and since there is a risk that insects, birds, and smaller mammals could be killed or hurt by traffic. The sealing of surfaces also makes the land unavailable for vegetation, making this a minor impact.

Air Quality

During construction there will be a lot of dust from demolition of buildings and digging in soil creating an increase of particles released to the air. Depending on the size and type of material this will have a different range

of spread and resident time. Old buildings can contain asbestos and radon, and when the buildings are demolished these materials can travel with dust in the wind. When the contaminated dust is inhaled it can cause severe health risks. This must therefore be handled with care.

The machinery used during the construction will release carbon dioxide and nitrogen oxide among others, which are known greenhouse gases. Nitrogen oxide also has direct health effects. Resident time for the gases released have lifetime from days to years and will therefore have a great impact on the air quality. Therefore, the effect on air quality is assessed as a major adverse effect due to its long resident time and the risk of releases of dangers dust.

When the construction phase transitions into the operating phase car traffic will increase in the area according to the project plan. That will, like the use of machinery during the construction phase, have a negative impact on the air quality due to the release of greenhouse gases. Therefore, its effect is assessed as major adverse compared to the baseline. Though the vision is that traffic will be electric vehicles, this is an optimistic vision and most likely will the vehicles be mainly driven on fossil fuel. Actual change has to be measured, but due to the prediction of increased traffic in the area there are reasons to believe that there will be a negative impact on the air quality.

There can also be some problems with the “green roads”, where the plan is to plant trees for other ecosystem services. However, if this is not well planned with selection and placement to promote good air flow there is a risk that pollutants and dust is trapped under the foliage. But the trees can also help with protecting from expositor to air pollution of people and animals (Shaneyfelt et al., 2017), concluding making the air quality better.

Urban parks might have a positive effect on the air quality, but is dependent on the type of vegetation and area (Paoletti et al., 2011; Nowak and Heisler, 2010). Here more research has to be done to make a good plan on how to plant trees and vegetation in a good amount and mix so that air quality can be enhanced. Though the effect of parks and other green spaces, like the green roads, might not be as comprehensive and is therefore assessed as minor beneficial, with an assumption that the project plan will take into consideration the mix of plants.

Surface water

The construction of the transport infrastructure as well as demolition and construction of buildings are likely to affect the quality of the surface water. The magnitude and the impact are therefore large and the recipient is sensitive to a decreased quality of water, therefore, the significance is assessed to be potentially major adverse for this indicator. Removal of vegetation in unexploited areas, transportation of materials, and excavation are likely to affect the quality of the surface water as well. Especially when it is such a large area that will be under construction at the same time. These impacts will be evident even at the beginning of the construction of the other phases as the majority of the water is drained towards the north and northeast part of the project area (through Phase 6). This will implement pressure on the Flemingsbergsvikens wetland-complex especially as the pond for sedimentation and retention purposes is supposed to be introduced later according to the Flemingsbergsdalen Planprogram as Phase 6 will be developed last (Huddinge kommun, 2019a). The volume of water discharging to the wetland-complex might also increase if the net evaporation will decrease and cause a larger pressure on the wetland-complex. The use of heavy machinery under the phase construction is likely to cause compaction and decrease the infiltration rate and generate more surface water. The use of heavy machinery and other

transports can also contaminate the area with oil spills and in this way affect the surface water quality. This emphasises the potential major adverse effects, see Table 9. All the different actions (1-4) under the construction phase will have a potential major adverse effect on the surface water.

Buildings are likely to add to the amount of sealed surfaces in the area, unless they are constructed with green roofs that can mitigate the response to rainfall. Therefore, this impact is assessed to have a potential minor adverse or beneficial effect on the surface water. This is important to bear in mind in the detailed planning of the project as it is likely to affect the surface water in a positive or negative way depending on the amounts of green roofs. Waste generation during the operation phase is considered to have a negligible effect on the surface water assuming that the waste is being dealt with properly. In the operational phase there will be a large amount of the area that will have impermeable surfaces. This will cause increased surface water runoff and if the stormwater is not handled to cause a retardation, using preferably green solutions to handle this it can cause a major adverse impact. It is problematic with more surface water generation as this produces a larger pressure on the wetland. If the wetland is receiving too much water without proper retention of water at precipitation it might reduce the purifying capacity of the wetland-complex. This is problematic as this can affect lake Orlången in a way that decreases its ecological and chemical status. Traffic can cause spills of fuel and oil, cause wearing of the roads and particles from tires and metal particles from studs. Traffic is assessed to have a minor adverse effect on the surface water. It is assessed to have only a minor impact as it is stated in the project plan (Huddinge kommun, 2019a) that most of the transportation in the new area will be made by other forms of transportation.

Parks and green spaces are likely to have a major positive impact on surface water. Green spaces can increase infiltration and percolation of water and also purify the water to some extent and cause a retention in the response to heavy rainfall and prevent flooding of buildings and important infrastructure. Therefore, this is assessed to have a major beneficial effect.

Groundwater

Construction of infrastructure, removal of existing roads and buildings, excavation and blasting can cause impacts on the groundwater quality. As presented in the baseline of Phase 6 there are several areas with contaminated soil. Based on the areas in Phase 6 with potentially contaminated soil in combination with the sensitivity of the recipient, the significance of the impacts on groundwater during the construction phase is assumed to be potentially major negative. Different activities can cause mobility of different pollutants to be transported to the groundwater as surface water can infiltrate and cause contaminants to leach into the groundwater and start to migrate from the pollutant source. There are several industries in our area and depending on their activity, removal and/or decontamination of contaminated soil might be necessary, to ensure that there will not be a spread of contaminants to the groundwater. It is important with sanitation of contaminated soil and protection of the groundwater as Phase 5-6 are planned to have recreational environments, parks, preschools, schools and a sports centre with many young visitors. During the construction phase the risk of contamination is most significant, but if contaminated soil is removed it can potentially increase the status of the groundwater in a long-term aspect. Data on groundwater quality has not been found and therefore it is important to emphasise that this impact assessment is based on assumptions. Depending on the composition of the bedrock, the blasting of bedrock can cause slight acidification (Trafikverket, 2015). However, it is mentioned in the Flemingsbergsdalens Planprogram

(Huddinge kommun, 2019a) that the topography will not be changed much in Phase 5-6. Therefore, this impact might be negligible. However, based on the precautionary principle and the knowledge that there are contaminated sites in the area all actions at the construction phase.

Exploitation of unused areas and increasing the amount of impermeable surfaces in the area are likely to decrease the infiltration of surface water to the groundwater. This is problematic as the flood risk increases. Sealing of surfaces can also be problematic for the generation of new groundwater. Most of the area will be modified and potential permanent or temporary lowering of the groundwater level in areas with much clay or fine sediments might have problems with subsidence. This is especially problematic when the soils will be under pressure from heavy infrastructure and roads (SGU, 2017). Subsidence might affect house foundations, roads, pipes and electricity cables (SGI, 2019). The groundwater level is relatively high in the low-lying parts of mainly Phase 6 (Structor, 2019). These areas might therefore be subject to different measures to lower the groundwater table. If this is the case these areas might be sensitive to subsidence. Sealed surfaces are therefore estimated to have a minor adverse effect. It is not considered major as there will be parks and areas without seals surfaces in the region according to the plan program (Huddinge kommun, 2019a). Traffic might have a minor adverse effect on the groundwater quality based on the potential release of heavy metals and other pollutants from for example oil spills that can infiltrate to the groundwater.

Parks and green spaces are planned in Phase 5-6 according to the Fleminsbergsdalens Planprogram (Huddinge kommun, 2019a). Parks and green spaces are assessed to have a positive impact on the groundwater as this will enable infiltration and percolation of surface water. Increased percolation of water to the soil might also have a remediating effect on the water, before it will enter the Flemingsbergsvikens wetland-complex and this is also considered beneficial. The lack of information about how the parks and green spaces will be constructed and designed makes it difficult to assess whether the parks and green spaces will have a minor or major beneficial impact on the groundwater.

Noise

During the construction phase of the project there will occur problems with high noise levels. Phase 5-6 is located close to a nature area which will be highly disturbed by noise from heavy machinery, construction, and potential blasting for example. This will mainly impact the people working on the construction site since there are no current residents in Phase 5-6.

As for the natural environments, studies have shown that noise pollution can affect the fauna. Many animals are dependent on their hearing. Animals react to noise in the same way as humans to some extent in the way that background noise can cause stress and change in behavior and sudden noises can cause fright (Sveriges radio, 2015; Buxton et al., 2017).

Since Flemingsbergs nature reserve is close to the project area, noise pollution especially during the construction phase, will have consequences. Another example is the bird life around the wetland. Noise pollution could disturb the birds, especially during spring when man species are extra sensitive according to JO Helldin (Sveriges radio, 2015). The communication needed for reproduction, warning and navigation can be greatly affected (Bergsten et al, 2016) if the communication between animals is disrupted, muffled or in other ways interfered with. For example, noise pollution could make it more difficult for predators to find their prey (SVT, 2017).

The impacts in the raport matrix are assessed to be major adverse impacts because the difference between baseline conditions and the construction phase of the project are expected to be major, especially considering sudden loud noises caused by construction.

During the operation phase, the noise level must be taken into consideration in order to prevent negative impacts on human health. Noise can affect the ability to sleep, impair the ability to concentrate, to learn, and decrease performance (Folkhälsomyndigheten, 2019). The risk of heart diseases and hearing loss also increases during long term exposure of noise. Therefore, it is important to take measures to minimise the noise exposure on the residents and, the children in preschools and schools in the area.

In Phase 5-6 there will be a limited amount of residential buildings creating noise, however the phases will contain several schools, preschools, and a sports centre that may produce high noise levels. An increase in noise from traffic is also to be expected from the developments nearby. The noise from the area will probably be greater during daytime and very limited during night. It is possible that the overall noise levels in Phase 5-6 will decrease since all industrial activity will be removed from the area and will be designed to suit schools and preschools. However, the amount of sealed surfaces will increase slightly in the area, creating an environment where noise easily amplifies in comparison to green spaces or softer surfaces. Thus this problem is greater in phases of the project with more dense housing plans, therefore Phase 5-6 highlights noise as mostly minor adverse or not applicable in the matrix (Huddinge kommun, 2019a).

Soil

During construction of Phase 6 there will be some risk of disturbing the soil. The activities that are taking place on Jonvägen and Regulatorvägen, referring to the bakery and stone worker for example, are known practitioners of dangerous substances. However, according to Huddinge kommun (2019a), the only area with potential high risk of contamination is the bakery. Other areas have a low to medium risk of contamination. There is a risk of releasing heavy metal through the present soil conditions, reducing this risk is of vital interest since Flemingsbergs day water system will connect to this area. The planned location of the pond currently in an area of moderate to low contamination of metals and PAH (polycyclic aromatic hydrocarbon).

The contaminated soil will be a problem during the construction of infrastructure and buildings where mainly already managed land will be used. These areas can contain contaminants from previous industries. Furthermore, when land is moved the soil that contains the contaminants might spread and cause pollution. These are assessed with a minor adverse effect, since the effect is short term, as soon as construction stops the contaminants will stay where they are.

To exploit unused areas during the construction phase might have a minor adverse effect since the work might change the soil composition and also strip the soil down to bedrock creating weathering that might affect the groundwater.

During the operating phase the soil will be impacted by the traffic. In a study performed in parks in close relation to roads and industry in Hong Kong there has been observed effect of higher amounts of heavy metals which are traced back to the traffic and vehicle tires (Li et al, 2001). Both Phase 5-6 will have new city roads which are planned to have high flows of traffic will be working as a passing through road (Huddinge kommun, 2019a). The metals that deposit from the dust created by traffic will be in

the top layer of soil and therefore easily transported through the flow of water. This will have long-term effects on soil quality and is therefore assessed as a major adverse impact.

The planned park might have a good impact on the soil due to the planned work regarding organic matter and filtering capacity. Though, if the soil diversity and soil organic carbon decreases in the planned parks and other green spaces in the current green structure, it might affect the soil's function to act as a carbon sink and its water-holding capacity (Laban et al., 2018). The park is also at risk for trampling from visitors. Effects have been detected especially in sites where there are slopes, though the greatest damage was made by motorcycles (Weaver and Dale, 1978), however, this should not be a problem for this area. Other studies on city parks in Hong Kong have even shown a positive effect on erosion (Jim, 1987). Due to the planned increase of visitors there will be more trampling in the area however, the effect will be minor adverse due to the change from the baseline conditions.

3.1.4.2 Cultural Environment

Cultural Heritage

All the known historical sites and relics are already examined and have been removed from the site. However, this is not done for unexploited areas (Henriksson, 2019). Phase 5 contains some unexploited forest areas where it could be of interest to conduct such an examination. However, since it is a small area with relatively young forest the likelihood of there being historically important relics there is small.

As for other cultural heritage impacts there could be an argument made for the industrial landscape as a kind of cultural landscape from the 80s that would be lost during the construction of this new development. Generally, this is not a currently desired landscape and will most likely not be missed. Therefore, the impacts of removing this landscape will be considered as low.

Visual Landscape

During the construction phase the visual landscape will change from an industrial landscape to a construction site, however, there are no residents living within the project boundaries that will be affected by the change. Therefore, the impacts during this time are assessed to be minor.

A neighbourhood dominated by schools, preschools and parks are more pleasant to look at and be in compared to an industrial landscape. The visual landscape will be improved by the construction of this project. Instead of a grey industrial landscape there will now be a modern and green, which most people find more appealing. The newly constructed buildings aim to utilise natural light and optimise sunlight (Huddinge kommun, 2019a). By not creating too many shaded and dark areas the neighbourhood will look and feel more appealing.

The current forest area in Phase 5 is not an inviting forest, it is difficult to access and does not invite people to interact much with it. By opening up and integrating the current forest to the planned park area it can become a place that feels welcoming and fun to be in.

With this in mind the impacts of the project in terms of the visual landscape is assessed to be majorly beneficial compared to the baseline conditions.

3.1.4.3 Socio-Economic Environment

Housing

Construction of the project will overall lead to more housing in Flemingsbergsdalen. This is a desired impact of the project since more housing will lead to an increased population and also more work opportunities. For the project to fulfill the goal of creating a living city, good housing opportunities is one of the most important tasks to reach. There will be minor construction of residential areas in Phase 5-6. There will be a scarce residential area with large green areas in between since the main focus of these phases are the recreational parks and schools. The large green areas could have a positive impact on the stress level among the residents. However, it could also have negative impacts with poorly lit green areas during evenings that feel unsafe to move in, for more in depth information see Section: 3.1.4.1 *Natural Environment* subsection: *Safety* in this Chapter.

The housing will have a negative impact on nature and biodiversity in the area since an increased population will cause more pressure on the natural environment with consequences such as light and noise pollution. For sensitive species this can cause problems such as behavior disturbance and loss of habitats. For example, an urban environment is often drier and hotter than the surrounding climate because of the material and design used in construction. A dry and hot climate disfavours species in need of humid areas such as amphibies (Persson and Smith 2014). For more information and examples of habitat loss, see Section: 3.1.4.1 *Natural Environment* subsection: *Noise* in this Chapter.

The wetland close to the phases has a rich fauna with some sensitive species such bats, amphibians, and birds that live in the wetland could be negatively affected by the artificial light coming from housing development (Rich and Longcoe 2017; Laantee and Strid 2002).

Currently there are no residential buildings in Phase 5-6, therefore many of the actions in the report matrix for Phase 5-6 is irrelevant to speculate upon. However, a positive development for housing will occur because the project will construct several buildings in the area while maintaining an open and green environment.

Recreation

There are currently no recreational facilities or areas within the area and therefore there will be no impact during the construction phase. However, during the operation phase the possibilities for recreation within both phases will improve immensely with the construction of recreational parks, schools and schoolyards, and the sport centre that will be located there which will promote physical activity and social interactions.

One of Flemingsbergsdalen's larger parks will be located in Phase 5. The park provides many options for recreational use since they can be used for play, sports, working out, or as a place where people can come to relax and meet others. Boverket (2018) states that higher quality of open green space will increase the amount of time that children spend outside, which is why the quality of the parks have an important role in terms of recreation but also for physical- and mental health. Not only for children but for all the residents of Flemingsbergsdalen. It has been shown that urban greenery and parks can have very positive effects on human health, according to Haq (2011), the benefits from visiting green spaces are that residents feel less stressed and may even make them less susceptible to stress to begin with.

More traffic such as cars would likely decrease spaces use as recreational if it makes them feel unsafe, for more information see section about Safety below. However more space for bicycle use and walking would be a considerable improvement since there are currently no pedestrian streets in the area.

Since there currently no recreational facilities in the area the project will increase the recreational value of the area and therefore the impacts during the operation phase are assessed as major beneficial.

Health

Currently there are no residents in Phases 5-6, making the impacts from noise and degraded air quality during the construction phase negligible. However, the construction workers need necessary equipment to maintain their health, concerning for example noise, air quality, vibration, and strain on the body (Arbetsmiljöverket, 2015). But since it is assumed the construction workers use the required equipment and follow the recommendations, this impact is also assumed negligible.
During the operation phase, the noise level, air quality, and aesthetics of the area must be taken into consideration in order to prevent a negative impact on the health of the residents and visitors. The planned park in Phase 5-6 is assessed to have a major beneficial impact on health, since this constitutes an area for recreation. For more information see Section: 3.1.4.1 *Natural Environment,* subsection Noise; 3.1.4.2 *Cultural Environment,* subsection *Visual Landscape* and Section: 3.1.4.3 Socio-economic Environment, subsection *Recreation*. The air quality must be kept within the thresholds, especially since there are preschools and schools planned in the area. The risk of children in preschools and schools being affected by bad air quality and noise is heightened in Phase 5-6 according to the project description (Huddinge kommun, 2019a). It is, however, difficult to assess the impact on the health since more information is needed.

Safety

During the construction phase it is important to create a safe working environment to ensure that no accidents occur. An inventory regarding which companies that are handling dangerous goods that can have sudden accidents risk, both for the area and those who will do the construction there has been created for the project area in order to decrease the risk of accidents and ensure safety.

According to the Swedish Arbetsmiljöverket, it is every employer's responsibility to create a systematic work environment description before the project can even start. The plan has to state the rules that apply on the work site, a description on how the working environment should be organised and mitigations strategies to avoid accidents (Arbetsmiljöverket, 2015). Though there is a high risk of work accidents in the construction industry, almost twice as high as other professions, it is not likely that there will be any major accidents if the employer establishes a good description of working environment before construction starts (Arbetsmiljöverket, 2018).

There might also be some risk for the civilians moving in the area since there will be heavy machinery and dangerous construction materials present. However, civilian activity is already low, as noted during the site visit, since the project area does not have any residential buildings. Therefore, the impact is assessed to have a 0 impact (L:1-4) in Table 9, due to the low risk for both civilians and workers. The risks are also limited to the construction time, which further decreases the impacts.

By increasing the day and night activity in the area during the operating phase, the project intends to increase the feeling of being safe and to reduce crime (Huddinge kommun, 2019a). Crime does not seem to have been a large problem in this area before, however, the feeling of general safety has been reported for the surrounding area like Visätra, to have a perception of general unsafety (WSP, 2019a) (see figure 36).

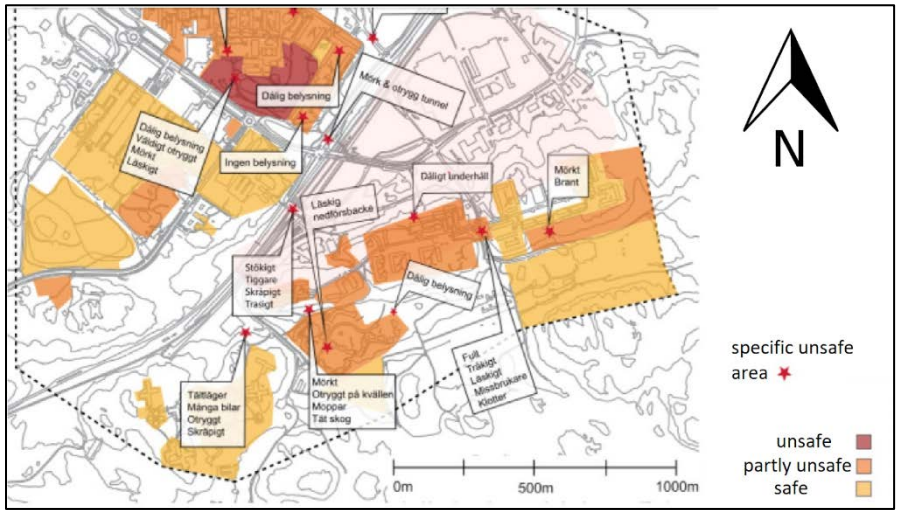


***Figure 36**. Map over reported unsafe areas in Flemingsbergsdalen (WSP, 2019a).*

To have a dense housing area could lead to a safer environment where citizens feel safe both night and day. A dense area could lead to more activities and organizations where people can participate and be useful. However, it could also be the opposite. Densely populated areas could lead to conflicts and trouble between people and groups. Depending on the construction of the area many people in a small space can cause stress and irritation. High standards on the commute alternatives and public organization are required.

Adding the residential buildings and public facilities in Phase 5-6 might not be enough to ensure that this perception of unsafety will not spread to the new area. Light is an important factor for the feeling of being safe but also combined with social safety. Perceived safety changes with lower light but it can be tolerated when social safety is not threatened (Boomsaga and Steg, 2012). According to Bennet et.al (2007), people and especially women, in low-income neighborhoods feel generally unsafe during the night hours. This will make them less likely to be active in the neighbourhood which might cause less activity outside during the night (Bennet et.al, 2007). In Phase 5-6 there might be some complications with the perceived safety, since there will not be as many residential buildings compared to other phases. There is also a sports centre that might cause a bit of a turbulent environment depending on what kind of event that is hosted there. The park separating the area from Visättra might cause safety concerns if it is too dark night during the hours and the activity level is low. A good plan is therefore needed to ensure that people feel safe.

The area of Phase 5-6 is of special concern since there will be a large amount of children around due to the many preschools and schools, but also because of the expected visitors to the park. A study made by Björklid (1994) showed that anxiety and fear, which can be related to children's safety increases with more car traffic. Fear is not only for physical accidents but also for other variables such as noise, air pollutants, and mobility restrictions. The study highlights the importance of adult supervision (Björklid, 1994).

Traffic incidents leading to crashes is highly associated with the design of the neighborhood (Dumbaugh and Rae, 2009). In Dumbaugh and Rae's empirical study they found connections between "big box" stores and an increase in incidents and injuries. This could be correlated with the sport

centre in Phase 6, where there might be a larger parking lot and many people moving around at the same time. However, the study also showed a decrease in injuries and crashes where communities were densely populated and had normal pedestrian numbers (ibid.). Increasing car traffic in Phase 5-6 will increase the pressure on traffic safety in the area.

The impacts on safety in concern of crime might be like the project plan implies that where there will be a lot of “eyes on the street” there will be less crimes. But when considering the perceived safety the public facility in the area might be of concern. Therefore, public facilities have been assessed as minor adverse, since it will be one time event things happening and not an everyday problem. Residential buildings' effect on safety is assessed to be major beneficial both in aspect of crime and the aspect of perceived safety.

The plan is to redirect traffic to streets in the outskirts where they plan for a high flux of cars, this to reduce traffic in the central parts. These are called city streets and are passing the schools and preschools in Phase 5-6 (Huddinge kommun, 2019a). Since there will be a lot of children in this area this will have an impact on the perceived safety (Björklid, 1994). However, traffic might be of minor adverse concern, though it is highly dependent on the design (Dumbaugh and Rae, 2009), the assumption still is that project traffic design is well planned. Regarding the park area city park Visättra, there is currently no description of lightning in the area, which is something that could improve the safety. It is important to communicate with the project planners that there will be a large open area with good vision during the day, however, this will not help during the days darker hours unless there is a plan for creating good lighting conditions. The effect of parkes and green spaces is there for assessed to have both major adverse and beneficial effects on safety.

Equality

Some of Fabeges’ previous projects in Stockholm include Hammarby Sjöstad, Haga Norra, Arenastaden, and Stockholms inner city (Fabege, 2019c). All of these areas are high-end, exclusive, and very expensive areas to live in. Fabege has a particular style and will therefore attract a certain group of people. As the housing prices in the areas previously mentioned are very high for both rental apartments and privately owned apartments, it can be assumed that Flemingsbergsdalen will follow by the same standard and prices. This makes it impossible for many to establish themselves in the area and will exclude lower income households. There is a massive housing shortage in the greater Stockholm region and in Huddinge, new developments like these are necessary but also bring problems of inequality and gentrification when the new areas become too expensive for the current residents that can no longer stay in the area due to rising prices.

As there are no previous residential areas in Phase 5-6 there are no residents being removed for the project development. Which is why the residential development in the area is viewed as a positive impact for these phases. In Phase 5-6 there are a few housing units, but mainly schools and preschools, the children in these schools will likely come from quite similar socio-economic groups. Which means that they will not be as likely to be naturally exposed to different cultures and family constellations in school. However, schools and preschools do have the ability to be open and accessible for all socio-economic groups and could potentially have a positive impact on equality. The impacts are therefore assessed to be major beneficial.

The parks in Phase 5-6 will be accessible for everyone in Flemingsbergsdalen and can be a meeting place for people of different ages and abilities to come together and enjoy the outdoors. However, since areas that contain urban greenery are more visually appealing it may increase the property values even more (Haq, 2011), making urban spaces an impact that may also bring with it gentrification which would be negative for equality. There are currently no concrete plans for how the parks will be designed, but done right they can have a positive impact for accessibility and therefore equality. Therefore, the impacts are assessed to be major beneficial from the construction of parks and green spaces.

Employment

It is uncertain how many people are employed within Phase 5-6 today, and because of this it is difficult to compare the expected opportunities with the current number of employments. But generally the project is expected to create many new employments. The demolition of the old buildings and the construction of the new infrastructure will create many job opportunities, especially within the construction and transportation businesses.

During the operation phase preschools and schools will create new employment opportunities for teachers, preschool teachers, cleaners, and janitors. Residential buildings, the mobility building, the sports centre, and the parks in the area will need personnel for jobs such as janitors, cleaners and park maintenance. Since there are no commercial buildings in Phase 5-6, these impacts will be considered as negligible.

Accessibility and Connectivity

Compared to the baseline the accessibility to the area is likely to be decreased during the construction phase. There are currently no residents within Phase 5-6, but people working in the area and people using Regulatorvägen and other roads in the two phase areas for transportation might be affected negatively during the construction phase. However, this is considered to be minor negative as the magnitude and sensitivity is considered low as there are other transportation pathways and access routes. This is the reasoning behind why the projects impacts on accessibility and connectivity is considered to be minor negative during the construction phase.

One of the projects main ambitions is that the new Flemingbergsdalen will be an active city both during the day and nighttime (Huddinge kommun, 2019a). Phase 5-6 will offer short distances between residential buildings, workplaces, services, public transport, parks and nature, and the connectivity and accessibility will therefore be beneficial in the area according to this assessment. All residents and workplaces will be situated within 400 metres from a public transport option according to the Flemingsbergsdalen project plan (Huddinge kommun, 2019a). The accessibility and connectivity within and to Flemingsbergsdalen will be improved and is therefore seen as a beneficial impact.

The planning of the roads and thereby sealed surfaces will contribute to a major beneficial effect seen to improving accessibility and connectivity. The aim according to the sustainability program for Flemingsbergsdalen is that the majority of the transportation in Flemingsbergsdalen will be sustainable (WSP, 2019b). Flemingsbergsdalen will be built so that it will be easy to live there without a car and transportation by walking, biking or

using public transport will be prioritised. This will be a major beneficial impact for the accessibility to and within Phase 5-6. The socioduct that will be built from Regulatorvägen over to Tellusvägen, which is located north of Phase 5, will also increase the accessibility and connectivity to the area from this access route. The accessibility and connectivity to green spaces will increase and is likely to make both parks and adjacent nature reserves more accessible to more people. This is why parks and green spaces are predicted to have a major beneficial impact.

Table 9. *Impact matrix showing the assessed impact significance levels for the corresponding actions and indicators in Phases 5 and 6.*

		Construction Phase				**Operation Phase**						
	Actions / Environmental Indicators	Construction of infrastructure	Movement of land Demolition or buildings and removal of infrastructure		Exploiting unused areas	Public facilities	Commercial buildings	Residential buildings	Waste generation	Sealed surfaces	Traffic	Parks and green spaces
Natural	Biodiversity	- -	- -	- -	- -	-		-		-	-	+ / -
	Air (quality)	- -		- -							- -	+
	Surface water	- -	- -	- -	- -	+ / -		+ / -		- -	-	+ +
	Ground water	- -	- -	- -	-					-	-	+
	Noise	- -	- -	- -	-	-		-			-	+
	Soil	-	-		-						- -	-
Cultural	Cultural heritage		-	-								
	Visual landscape	-	-	-	-	+ +		+ +				+ +
Socio-Economic	Housing	+ +				+			-			
	Recreation					+ +					+ / -	+ +
	Health											
	Safety					-		+ +			-	+ + / - -
	Equality					+ +		+ / -			+	+
	Employment	+	+	+		+		+			+	+
	Accessibility and Connectivity	-	-	-		+ +		+		+ +	+	+ +

3.2 Summary of Impact Assessment

The impacts from the different phases were assessed in order for the cumulative and overall impacts for the entire project could be estimated. A summary of the impacts from all phases can be found in Table 10. The following section addresses the different categories of significance; major adverse, minor adverse, minor beneficial and major beneficial impacts in the summary matrix.

In total, for the project, 12 % of the indicators have been assessed as major adverse and 18 % as major beneficial. 27 % have been assessed as minor adverse and only 9 % have been assessed as minor beneficial. 31 % of the indicators were negligible. And 3 % have been assessed as both beneficial and adverse, with varying extents.

Major Adverse

The construction phase of the project will have a significant adverse impact on several indicators, described in detail in Section: 3.1 Planned Project. 23 % of the predicted impacts are assessed as major adverse during this stage of the process. The biodiversity in the project will be major adversely affected by the construction of infrastructure, movement of land and exploitation of unused areas. During the construction of infrastructure, noise levels are expected to increase and the movement of land is expected to destroy some soil diversity and vegetation. The exploitation of unused areas is expected to significantly affect all vegetation, soil and animals, which will be deterred or removed from the area. The air quality has been evaluated to be major adversely impacted during the operation phase, due to traffic. The main contributors to air pollution around the project area are the Huddingevägen and the railway for both the commuter and regional trains that are passing through Flemingsberg station.

The surface water and groundwater for the entire project was assessed to be major adversely affected during the construction phase (except for the exploiting of unused areas for groundwater). This takes into account that pollutants would drain into the nearby wetland, which is on the border of one phase of the project (Phase 3-4), and as such, is an extremity. In addition, the surface water is major adversely affected by sealed surfaces and traffic, because various modes of transport can emit aerosols, and result in fuel and oil spills that can be transported in the surface water (via the sealed surfaces) to the wetland.

Noise in the operation phase is major adversely affected by the increase of traffic that will inevitably result from more inhabitants and people moving through the area. The movement of land will majorly adversely impact the soil in the construction phase because this will aggravate the contaminants present in the soil. During the operational phase, traffic, parks and green spaces may have major adverse impacts on the soil. The traffic could result in the pollution of the soil from exhaust emissions, fuel and lubrication system leakages, component wear such as tyres, brakes and chassis and road surface wear (Goonetilleke, 2017). The green spaces with be majorly adversely impacted due to the surfaces of the green space serving as a gathering point for contaminated surface water from the neighboring phases in the southern part of the development. Unlike the majority of other majorly adversely impacted indicators, cultural heritage is considered an extremity value (not an average value of each of the Phases) because not every phase has cultural heritage, solely Phases 3-4 (with an unknown artifact) (Lantmäteriet, 2019). The cultural heritage in that phase will be majorly adversely impacted by the construction of infrastructure, excavation and demolition of bedrock and the exploitation of unused areas. This artifact may be possibly damaged by blasting (during any demolition

activities), excavation and the construction of roads, which may expose the artifact to the elements.

Minor Adverse

Out of all the impacts that the project will affect, 27 % will be minor adverse. This means they have a short-term negative impact, as compared to the baseline and that the impacts are reversible.

In the matrix, the main sources of minor adverse impacts are during the construction phase of Flemingsbergsdalen. 58 % of the predicted impacts are assessed as minor adverse during this stage of the process. During the construction phase; air quality, noise, visual landscape, recreation, health, safety, and accessibility have all been assessed to have minor adverse impacts. All phases have been assessed and the impacts are due to the beginning construction, which will significantly change the area. The use of heavy machinery and digging in soil will release a lot of NOx and CO_2 into the air (among other particulates), and will create noise. More information about this can be found in the individual phases. There may be risks with construction, however, with the proper health and safety precautions, especially for construction workers, the impacts will be minorly adverse. For more information, refer to the section on safety in Phases 5-6. There are not a lot of recreational activities in the area currently, except for some cafes, gyms, and a library that may be affected, for more information please see Phase 1.

Groundwater and soil will be minor adversely affected by exploitation of unused surfaces and the construction of infrastructure during the construction phase. The area's cultural heritage will also be subjected to minor adverse impacts, from the exploration of unused land, however, the majority of the impacts for this action are major adverse and are explained further in subsections regarding Groundwater in Section: 3.1 Planned Project. The sealing of surfaces in the area may increase the flooding risk, which can prove problematic for the generation and flow of groundwater. This will probably be a minor adverse impact in the entire project area, but is further investigated in the impact assessment on groundwater in Phase 5-6.

There are also some indicators where the impacts are assessed to be minor adverse during the operation phase, 8.6 %. The most prominent indicator is biodiversity, where four out of seven impacts are assessed to be minor adverse. The impact of buildings, traffic, and other project activities on biodiversity can be found in the impact assessment section of Phase 5-6 (Section: 3.1.4 Phase 5-6 Recreational Parks and Schools). Groundwater will be minor adversely impacted during the operation phase by the sealing of surfaces and stormwater management. Traffic is assessed to impact the air quality, further information can be found in the impact assessment for Phase 5-6 (Section: 3.1.4 Phase 5-6 Recreational Parks and Schools). The sealing of surfaces over the whole project will minor adversely affect the noise levels, due to the fact that the noise absorption of softer surfaces disappears when surfaces are sealed. Further information regarding the noise can be found within impact assessment for Phase 2 (Section: 3.1.2 Phase 2 Overlay Development).

The cultural heritage will be minor adversely affected by impacts in the operation phase from traffic, green spaces and parks due to acidic rain, traffic emissions and vandalism. Cultural heritage impacts may be a problem in Phase 3-4, but a significant change in this phase will impact all potential visitors in all phases. The green spaces, green roofs and parks within the project area will have similar issues in terms of the fact they will

be planned in several different locations in the area and the impact on them will affect visitors throughout the development.

All minor adverse impacts can be mitigated, so it is important to examine these and see what could be done to reduce or remove these impacts. More details about the different impacts and their causes can be found in Section: 3.1 Planned Project and mitigation in Chapter 4: Mitigation Measures.

Minor Beneficial Impacts

The project is considered to have a net minor beneficial impact on employment within the construction phase. The employment opportunities that arise during this phase are only considered to be minorly beneficial, as the jobs provided will be short-term and on an as-needed basis. It is important to note that while the sealing of surfaces requires workers, the number is assumed to be minimal and integrated within the workers already performing other constructional activities; thus, the identification in the impact matrix was determined to be negligible. Additional employment opportunities will also arise with the operation of public facilities and public transport. The operation of new public facilities, such as schools and sports centres, will require individuals of various professions to be hired. While these jobs will provide long-term employment opportunities, the number of jobs created from these facilities is considered to be much lower than those that will be created from the operation of commercial buildings; therefore, public facilities are considered to only have a minorly beneficial impact on employment. Furthermore, the project aims to expand the public transport sector, thus creating additional jobs for bus, train, and tram drivers. However, seeing as public transport vehicles in the area already have drivers, the number of individuals to be hired is expected to be quite low compared to that of other sectors.

Aligning with the vision of the project, Flemingsberg seeks to be a relatively car-free city. The displacement of cars outside of the city and expansion of the public transport network will promote equality by relieving the societal and economic pressures of owning a car. With an increase in more accessible and cost-friendly modes of transportation, individuals of all income brackets will have equal opportunity to travel within the area. Therefore, the expansion of public transport is said to have a minorly beneficial impact on equality.

Under the assumption that the project is to implement green roofs on buildings, buildings in the area will have a minor beneficial impact on stormwater. This is due to the fact that green roofs possess the ability to both improve the quality and decrease the quantity of surface water that reaches the wetland-complex near Phases 5-6. Courtyards within buildings are also capable of doing this, so long as the surfaces used to construct the courtyards possess infiltrative abilities.

The operation of parks and green spaces will have a minorly beneficial impact on biodiversity, groundwater, noise, safety, equality, and accessibility and connectivity. Seeing as Flemingsberg currently has a lack of parks and green spaces, their implementation into the area will promote biodiversity, through the creation of small biotopes, and increase the permeability of surfaces, thus increasing the amount of groundwater that is able to be stored by the surfaces. Additionally, the softer surfaces, in comparison to the hardened surfaces that currently exist, absorb more noise and heat, thus acting as noise dampening and cooling mechanisms for cities, respectively (WHO, 2019a). The addition of parks and green

spaces can also provide individuals with safe areas for recreation (ibid.). In general, parks and green spaces are public property, and therefore, accessible to everyone for recreational use. Thus, this is considered to have a minorly beneficial impact on both equality and accessibility and connectivity as well.

Summary of the construction phase shows 5 % of the indicators that are assessed will have a minor beneficial impact. That change at the operating phase when 11 % of the indicators have been assessed as minor beneficial.

Major Beneficial Impact

During the construction phase, there are no actions that are considered to have a major beneficial impact on any of the indicators. The major beneficial impacts are seen during the operational phase (28 %), mainly from the operation of public facilities, commercial and residential buildings. Most of the impacts that will receive the major benefits are of cultural and socio-economic nature. This includes the overall improvement of the visual landscape after the development of Flemingsbergsdalen. Today, the area consists mainly of small roads, parking lots, offices and a train station. The operation of the buildings will greatly improve the socio-economic environment.

The addition of the sport centre, shops and public walkways or bike lanes will fulfill residents' recreational needs and greatly improve people's general physical and mental health. The construction of more commercial buildings and offices would shorten many peoples' commute drastically, making it less stressful, thus increasing their quality of life. The development of residential areas would benefit the housing situation in Flemingsbergsdalen, as the district currently lacks sufficient residential areas.

Health and safety would also improve substantially after the development of residential, public and commercial facilities. Flemingsbergsdalen is aiming to become an urban business district with an active residential area. Based on the "eyes on the street" theory by Wekerle (2000), this would increase the area's feeling of safety. It would also increase access to socio-economic opportunities by increasing the connectivity within the district and with the rest of Stockholm as it will greatly improve with the development of paved roads and traffic systems. The natural environment of the area will not see any major improvement during or after construction, other than the development and management of parks. The parks will regulate and filtrate polluted surface water from the districts, before it is transferred to the respective recipients. Large green spaces will be placed at low elevations and function as collection areas for surface water in cases of heavy rainfall. Parks will also have a major beneficial impact on the visual landscape of the area, which will also improve people's mental health of not feeling trapped inside a concrete jungle. In addition, green spaces will also work as a form of recreational centre for people to do physical activities, which will also positively improve their physical health. Green spaces can also work as carbon sinks by absorbing the CO_2 in the atmosphere, which greatly improve the air quality (Paoletti et al., 2011).

Aspects with Beneficial and Adverse Impacts

Sealed surfaces within the area were determined to have both minor adverse and beneficial impacts on human health. Firstly, a general increase in sealed surfaces in densely built urban areas leads to the further retention and emission of heat (Ward et al., 2016). This in turn, makes people more susceptible to heat exhaustion, and in extreme cases, heat waves. However, seeing as the majority of the area is already covered in hardened surfaces, the impact is considered to be minor. Contrarily, an increase in sealed surfaces, such as pedestrian walkways and cycling paths, can be beneficial

for health, as they provide individuals with more opportunities to utilize active modes of transport. With more paths to utilize for active modes of transport, such as walking and cycling, Flemingsberg will experience a switch from passive to more active modes of transport. Seeing as the area is currently dominated by cars, this switch will have a majorly beneficial impact on both physical health, as more people will be active, and air quality, as less cars within the city will mean less exposure to high levels of air pollution (Banister, 2008). However, traffic is also expected to increase along Huddingevägen and the railway. This will have an adverse impact on health, as noise levels and traffic-induced emissions are expected to increase. However, with noise-dampening mechanisms, such as the overlay, and a switch to more active modes of transport within the city, the impact is only considered to be minor.

As mentioned above, local traffic, in all forms, is expected to increase with development, which in turn, will be beneficial to safety in the area. At present, Flemingsberg is not considered to be a very safe area, as it has very little pedestrian and bicycle traffic during the day and virtually no traffic at night. Therefore, with an increase in traffic on the streets, at all hours and in all forms, individuals will feel a greater sense of safety and security when passing through the area. This will considerably change the atmosphere in the city and be majorly beneficial in reducing crime and increasing a perceived feeling of safety. However, while local traffic is expected to increase, so is thru-traffic. Seeing as dangerous goods transport occurs along Huddingevägen and the railway, an increase in thru-traffic along these routes will result in a higher risk for accidents. While accidents resulting from dangerous goods transport can result in dire consequences, the likelihood of an accident is low; therefore, the impact of traffic on safety can be considered minorly adverse. Thus, traffic can be said to have both a major beneficial and minor adverse impact on safety in Flemingsberg.

Due to lack of clarity in building design, the effect of buildings on air quality can be adverse or beneficial. Generally, buildings are capable of manipulating air flow and trapping pollutants between them, thus adversely affecting air quality within the city. However, large buildings are also capable of blocking pollutants entering the city from larger roads, such as Huddingevägen. Therefore, depending on the design and scale of buildings, impacts on air quality can be either minorly adverse or beneficial.

Table 10. *Impact matrix showing the assessed impact significance levels for the corresponding actions and indicators for the entire project, inclusive of all phases.*

		Construction Phase				Operation Phase						
	Actions / Environmental Indicators	Construction of infrastructure	Movement of land	Demolition of buildings and removal of infrastructure	Exploiting unused areas	Public facilities	Commercial buildings	Residential buildings	Waste generation	Sealed surfaces	Traffic	Parks and green spaces
Natural	Biodiversity	- -	- -		- -	-	-	-			-	+
	Air (quality)	-	-	-	-	+ / -	+ / -	+ / -			--	+ +
	Surface water	- -	- -	- -	- -	+	+	+		- -	- -	+ +
	Ground water	- -	- -	- -	-					-	-	+
	Noise	-	-	-	-					-	- -	+
	Soil	-	- -		-						- -	- -
Cultural	Cultural heritage	- -	- -	- -	-						-	-
	Visual landscape	-	-	-	-	+ +	+ +	+ +				+ +
Socio-Economic	Housing	-	-	-		+ +	+ +	+ +				
	Recreation	-	-	-	-	+ +	+ +	+ +		+ +		+ +
	Health	-	-	-	-	+ +	+ +	+ +		+ / -	+ + / -	+ +
	Safety	-	-	-	-	+ +	+ +	+ +			+ + / -	+
	Equality					+ +	+ +	+ +			+	+
	Employment	+	+	+		+	+ +				+	
	Accessibility and Connectivity	-	-	-	-	+ +	+ +			+ +	+ +	+

3.3 Zero Alternative

The zero alternative takes into consideration the impacts the area will face, if the project is not to be implemented. The alternative examines the present status of the area and how it will cope with future, realistic changes (Glasson et al. 2012), such as an increase in population, traffic, and climatic changes. This is done by projecting and predicting the future state of the area's environment, using the baseline as a starting point. In addition, Huddinge Municipality has identified a few environmental aspects that may change significantly, if the area is not developed any further. This includes the risk for ineffective land-use, due to exploitation paired with a transport system that is not coordinated with the pace of housing development, as well as climate changes, such as heavier rainfall that could lead to lower water quality, health, and safety risks (Huddinge kommun, 2014).

3.3.1 Natural Environment

Biodiversity

The project area consists of some vegetation in the form of mainly forest, which has been assessed to be of natural values 3 and 4, which are deemed important for biodiversity. With the zero alternative, there will be no exploitation of the natural areas, meaning no direct effect on the biodiversity in the forests, assuming proper forest management is followed. The forest patches provide ecosystem services such as; biodiversity, filtration of water and air, surface water management and the regulation of some greenhouse gas emissions (European Union, 2013). However, the plan for Flemingsberg (Stockholms Läns Landsting et al., 2018) states that other areas around the project area will be developed, which include new housing developments and roads. In other words, natural environments around Flemingsberg will be deforested and exploited, fragmenting the landscape and potentially affecting ecological connectivity in the area. This in turn, could also affect the air quality due to decreased air filtration from deforestation.

Lake Orlången, situated near Flemingsberg is a part of the drainage system in Flemingsberg and functions as a recipient of the storm and surface water. The ecological status in Orlången has been assessed to be poor due to eutrophication and influx of contaminants such as lead and PBDE (Polybrominated diphenyl ethers) (Norconsult, 2017). Since there are industrial areas with contaminated land in Flemingsberg, situated in such a way that the surface water flows past these contaminated areas on its way to Orlången, the risk of continued contaminant influx to the lake is high. Good ecological status in Orlången must be achieved by 2027 (Länsstyrelsen i Västmanlands län, 2016) and with the existing drainage system, that goal in all probability, will not be feasible. Thus, the drainage system in consideration for the new development must be able to minimize the adverse effects on biodiversity.

Air Quality

Presently the air quality in Huddingevägen is good, but could improve.
Applying the zero alternative will worsten the air quality, due to the industries presently in the area, though the area is polluted now.
The area will become more air polluted from the below areas:

Carbon monoxide emitting from cars, trains and buses, increasing air pollution from traffic in the area like Tvärförbindelsen and from industrial combustion. Sulfur dioxide is also another thing which affects the air quality, its produced when coal and oil fuels containing sulfur are burned in power plants, industries and refineries, during the project power plants will be

used in order to access equipment and machineries thereby emitting these substances to the air, which as a result can cause health issues if the project is constructed. During the project more dust is generated from the renovation aspectings which is also a pollutant and could contribute to the air quality. Generation of waste may increase causing odour which will be flittered to the air around the Huddingevägen giving it an unfriendly smell, the more people we have in a particular area the more waste is being generated in that area.

Surface water

The surface water management in the area for the moment has several shortcomings. The major parts of the project area are drained through ditches towards the wetland complex. According to the company, Structor (2019), some parts of the project area have a high risk of flooding during periods of heavy rainfall. The highest risk areas are Flemingsberg train station and Huddingevägen heading towards Huddinge hospital (Structor, 2019). The quality of stormwater in the project varies in different areas due to the sealed surfaces and industrial activity. The wetland was constructed in 1995 to clean the stormwater and relieve the heavy eutrophicated lake Orlången. Recently, the contamination of the Orlången has decreased, but it is still is a far cry from from reaching good ecological status. High levels of phosphorus, heavy metals and PAHs (from industrial sites) are present in the lake. According to Tyréns (2019c), long-term industrial activities, from varnishing and plate companies, car washing and warehouses, are the source of the majority of the ground pollution in the area.

In the future, Flemingsberg expects to have an increase in population and therefore, also in traffic (Huddinge kommun, 2014). Increased traffic and industrial activity, together with climate change (which could cause heavier precipitation), will increase the rate (and quantity) of soil contamination. If this occurs, the surface water quality will likely deteriorate

Groundwater

The groundwater in the area are expected to be affected in different ways depending on the geological and hydrological conditions of the specific area. In the valley of the project area, where the centre (ICA Maxi and shopping centre) is located, the ground consists of clay (Structor, 2019). Due to the poor infiltration and percolation abilities of clay (Eveborn et al., 2017), the addition of groundwater in this area is expected to be low. The ground in other parts of the area (where the industries are situated) is till, which has a high infiltration ability (Eveborn et al., 2017) and since the ground contamination is at elevated levels in those areas, there's a significant risk that contaminants may reach the groundwater (Structor, 2019; Tyréns, 2019c). Thus, the groundwater quality is potentially at risk, and should be managed in such a way that the adverse impacts are minimised as much as possible.

Noise

Presently, Flemingsberg is a bit noisy as a result of some of the industries around there, a large population of people, migrating in and out, ongoing renovations, transportation and the present nightlife.

Applying the zero alternative will keep the area at its present state which is a bit noisy, a bit peaceful and calm. Hence proceeding with a project will subject the people to undergo more discomfort arising from future noises which usually arise from the whole construction process and renovations and the below areas:

public transportation from the use of buses, cars, subway trains to commute to work, more upcoming Industries who will love to start up in the area, tractors, and equipment used via the construction stage, overcrowding in recreational areas, restaurants and bars, tourist areas, individual apartments from parties and many more are all exposed to high levels of noise pollution as a result of a new project.

All of these during the project phase in order to make Flemingsberg a part of the urban culture and development of the area becomes an uncomfortable place, it stops becoming just noise and starts turning into noise pollution. For many, the concept of noise pollution is limited to nature and resources. However, noise that tends to disrupt the natural rhythm of life makes for one solid pollutant.

However, this will also disrupt the peace of the Medicinaren which is also suited in Flemingsberg, alongside its forestation, wide life and habitants.

Soil

The soil within the project area contains both low and high concentrations of contaminants. The industrial areas are especially exposed to pollutants. The contaminants are oils, heavy metals such as lead, PCB, petroleum hydrocarbons and other PAHs and organic- and chlorinated solvents. Since the ground of the industrial area consists of till the infiltration is efficient which elevates the risk of the contaminants reaching through to the groundwater. This is important to take into consideration because of the expected increase of precipitation due to global warming (Olsson and Foster, 2013), since that could increase the rate of infiltration and leaching of contaminants. This emphasizes that the soil of the area needs to be managed in such a way that the potential adverse effects are minimized.

3.3.2 Cultural Environment

Cultural Heritage

There are a few buildings and places within the project area that has been assessed to possess cultural values. Cultural heritage is protected by Swedish law (Riksantikvarieämbetet, 2017), therefore, there is no reason why this should be affected by the no action alternative.

Visual Landscape

Flemingsberg Centrum is comprised of newly built grocery stores such as ICA Maxi and Lidl, newly built apartments, parking lots, cultural and leisure centre including an indoor sport and training facility and a library. There are also institutions for higher education and research, as well as a law enforcement centre.

The northeastern side of the project area is covered by forest, however it is not easy to access and will likely stay this way. Except this forest part, most of the area consists mainly of concrete sealed surfaces for commercial and industrial use (Figure 18). Buildings have enough open space which receives the good amount of sunlight throughout the day however most of this open space is sealed and thus not have enough green spaces. Pedestrian and bicycle lanes not in very good condition which makes the area look less cared for. There are no parks within the proposed area and green patches are limited to small fragments between buildings and along roads. Further, social cohesion is prevented by Huddingevägen which is separating the area from the rest of the Flemingsberg as seen in Figure 12. The site is located in a valley and the surface level area is relatively uneven (Tyréns, 2019a). The low standard means, among other things, inconvenient slopes and curves and many conflict points with pedestrian

traffic. Today's congestion on commuter trains and buses in rush hour traffic is not sustainable now or for a larger population in the future. The overcrowded commuter trains and buses in rush hour creates an overall crowded feeling in the area, which is likely to get worse without new development. Flemingsberg have the urban qualities, but not the urban feeling. The area contains very low recreational values and thus will not have any impacts with zero alternative.

3.3.3 Socio-Economic Environment

Housing

Presently, the housing at Flemingsberg is affordable and spacious thereby resulting to a lot of population in the area. The housing area accommodates both international students, immigrants, Foreigners and the swedish indigenes who can not afford to stay in areas where housing is expensive.

Applying the zero alternatives leaves the housing at its present condition which is affordable as flemingsberg is known to have one of the most affordable housing in sweden and the housing is also conducive for the people. Flemingsbergs harbours over 18 000 students who come from all over the world to study in Sweden.

Reconstruction of the area will arise in rents, less population of the area as people will tend to migrate out to sort for cheaper accommodations, After renovation the rooms may tend to become smaller as they might want to create more spaces, this can also result to people migration out of Sweden and students transferring to other neighbouring countries to seek universities with more affordable accommodations or housing areas.

It comprises of and SSSB who owns about 300 student apartments and huge 700 respectively.

Recreation

The industrial area within the project has not been constructed in recreation purposes. Therefore, a very low recreation value is to be found. However, the area also contains green spaces with some and markedly ecological value (Huddinge kommun, 2019a). Near the project area, several recreational places exist such as the wetland complex and the nature reserve. Future plans for the Flemingsberg can affect recreation opportunities in a negative way. One major impact is the upcoming highway Tvärförbindelsen which very likely will affect the environment around the wetland with increased noise pollution and a chance of the visible landscape. An increase in population will put an increased pressure on the natural environment that exists in the area. If no actions to improve recreational value in the area is being conducted the existing values will most likely suffer. Therefore, the development will have none or a minor adverse effect on recreation.

Health

Flemingsbergsdalen is today dominated by different types of industries and workshops in the form of lacquers and sheet metal workshops, vehicle washes, etc. These industries are generating the substances which are hazardous to the soil and environment (Tyréns, 2019a). Therefore, can affect the health of people residing and working in the area.

Flemingsberg is crossed by both road Huddingevägen and railway, and due to the proximity to existing railway tracks, there is a risk of vibration in the building closest to the track area. The vibrations enhance the experience of

noise but also can be perceived as a disturbance in itself. One of the disruptions to daily activities is interference with sleep and relaxation (Kono and Sone, 1988).

The projected growth for the population in the Municipality is 21-49 % by 2030 (White Arkitekter, 2012). With the projected growth, road traffic is also expected to increase and so is the congestion. The noise can affect not only physiologically but also psychologically. According to the arousal theory (Ng, 2000), exposure to moderate or high intensity noise can result in a lack of concentration. Lowered concentration leads to a narrowing of an individual's attention. Noise from transportation can form a large part of the external noise affecting people and their surroundings. Domestic noises coming from lift, neighbourhood noises, are among the most frequently reported causes of annoyance and the most difficult to characterize and quantify. Near Huddingevägen, the noise level is above 75 dbA (Engström and Torehammar, 2013) and can cause health impacts on people living close to this road. Majority of North-East part of the Flemingsbergsdalen is covered with forest, whereas other parts are sparsely covered with green areas. Moving to greener urban areas was associated with sustained mental health improvements, suggesting that environmental policies to increase urban green space may have sustainable public health benefits (Alcock et al., 2014). At present, there are large areas with hardened surfaces in Flemingsbergsdalen. Buildings, roads, car parks and pedestrian walkways all absorb heat and increase surface and ambient air temperatures, and heat emitted from the use of energy in cities also contributes to higher temperatures. Increased urban temperatures can cause discomfort to city dwellers (EU, 2012). Lack of a common meeting place or a gathering centre is also creating a social barrier among the people living in and nearby areas. Around 73 % of Huddinge's inhabitants (as of 2017) work in other municipalities (Huddinge kommun, 2018) and it is not sustainable, from an environmental perspective, to only have business districts in the north, as people have to commute long distances to work. According to University of Surrey (2015) "The level of physiological, physical and societal stress that frequent travels places upon individuals has potentially serious and long-term negative effects that range from the breaking down of family relationships, to changes in our genes due to lack of sleep. Hence, there could be minor adverse health impacts with Zero Alternative.

Safety

The most fundamental requirement of a habitable building is that its occupants can live in it healthily and safely. The overall health and safety performance varied with building age and development scale – young buildings and large developments usually performed better (Wong et al., 2006). Due to the existing industries like paint welding, boiler, and a gas station in the area they themselves pose many safety risks as larger amounts of environmentally hazardous substances are handled in the form of petroleum hydrocarbons and organic solvents and metals. Secondly, Flemingsbergdalen area has more movement during day time than night due to industrial activities. Also, there is a lack of recreational and gathering places resulting in fewer opportunities to socialize and thus breed a sense of insecurity among residents due to large open areas and lack of urban qualities. A total of 28 % of the population (aged 16–84) state that they feel very unsafe or quite unsafe when going outdoors alone at night or that, as a consequence of feeling unsafe, they avoid going out alone at night (Brottsförebyggande rådet, 2019b).

Streets and roads are among the most exposed workplaces from an environmental and safety point of view (Asfaltboken, 2019). The terrain conditions as well as the road and track area create a number of barriers

that spatially and socially delineate and cut off the area from the rest Flemingsberg. Walking and cycling paths in the area are not continuous (Tyréns, 2019b). Huddingevägen is expected to increase to around 29 000 cars per day by the year 2040 (Henriksson and Fors, 2019) and hence could pose a safety risk to people. Further The inequalities currently exist in Flemingsberg's socio-economic environment, thus making it an insecure area to live in (White Arkitekter, 2012).

The wastewater system today receives unwanted additional water due to faulty connections and other deficiencies in the system. When it rains heavily, there is a risk of wastewater system leads to basement flood and to discharge it into storm water pipes, watercourses and lakes (ibid.).
Lastly, a power line crosses Huddingevägen in the upper part of the area and continues northward through to Flemingsbergs gård (Huddinge kommun, 2019h) and is again a risk to people being electrocuted in case of breakdown of any line. Thus, there could be major adverse impact on safety with Zero Alternative.

Equality

From the transport angle of equality, Flemingsberg has a good commuting system with the train and commuter-train station in the centre. It is easy to travel in and out of Flemingsberg. The project area however with the industrial site in the middle is an inaccessible area mainly built for cars. Flemingsbergsdalen has an insufficient number of connections for pedestrians and bicyclists over the big roads, railways and the industrial site (Huddinge kommun, 2018).

Equality must also be considered for people with disabilities, and includes many different parameters. In Figure 37, the diagram describes five different parameters of equality and accessibility (Huddinge kommun 2016). According to the diagram Huddinge performs above average in all parameters.

Accessibility for disabled people have not been assessed for the industrial areas within the project. The area is easily available by car for the employees, but mostly the public do not need to visit the industrial area daily. As for the more public parts of the project area, near ICA Maxi, the accessibility is not satisfactory for disabled persons according to the site visit. On the other hand, the associability to grocery, hospital and transportation for the people living near Flemingsberg central is beneficial.

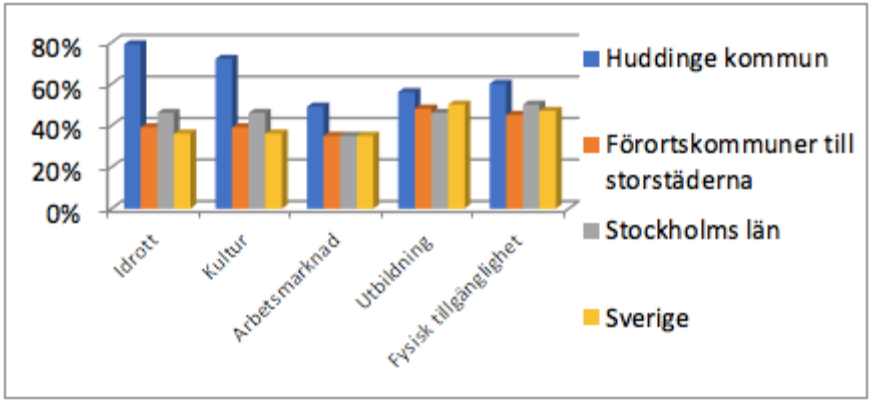


Figure 37. *Huddinge Municipality survey answer from 2016. Equality and accessibility for people with disabilities. Columns from left to right: sport, culture, labour market, education, physical accessibility. Column from top to bottom: Huddinge Municipality, suburban municipalities, Stockholm county, Sweden. (Huddinge kommun, 2016)*

The equality within the area do not expect to chance with the Zero Alternative. On the other hand, in the long run, population growth without development will most likely lead to a worse standard of living and poorer equality for the population in the area.

Employment

Most of the employment options in Flemingsberg are related to the waste management, car workshop, warehouses, and industries. Some of the jobs are also provided by Flemingsberg centrum. Unemployment rate for Flemingsberg's population (aged 18-64) was 5.1 % (Mar, 2019) which is more than the average unemployment rate of Huddinge i.e. 3.1 % (Huddinge kommun, 2019a). Furthermore, the median income of 306 099 SEK in Huddinge kommun (2018), compared to Stockholm 326 237 SEK, shows the most of the jobs in the area are providing low wages. With the zero alternative, the employment opportunities are expected to remain the same as of today and the trend of people working in North Stockholm is expected to remain the same. Especially since around 73 % of Huddinge's inhabitants, as of 2017, work in other municipalities (Huddinge kommun, 2018). However, the population is projected to increase by 37 % by 2028 based on Figure 38, so there will be major adverse impact due to increase in the unevenness of available opportunities.

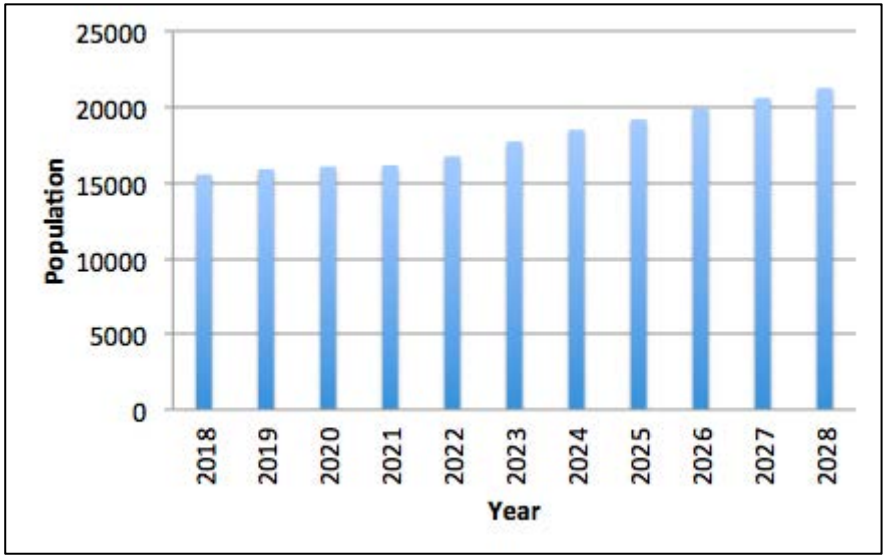


***Figure 38**. Flemingsberg projected population based on population prognosis between 2019-2028. The total change during the same period is 5 732 inhabitants.*

Accessibility and Connectivity

The connectivity of the area with the city centre of Stockholm is satisfactory due to the commuter train accessibility and Huddingevägen. However, the current connectivity with the areas east and south-east (Länna, Tyresö and Haninge) is poor. There is no direct connection of either public transport or any other transport. This will be improved with the construction of Tvärförbindelsen Södertörn, which will connect the above mentioned areas, by public transport, cars, and bicycle paths. Tvärförbindelsen will also be the new road for dangerous goods (Trafikverket, 2016) which will improve the safety on Huddingevägen and by that also improve the safety in Flemingsberg.

The connectivity within the area is poor. Since Huddingevägen and the rail goes through the Flemingsberg and thereby dividing it into two parts. The connection between the two parts are unsatisfactory with only two bridges. Regulatorbron allows both cars, cyclists, and pedestrians to pass while the other bridge is only for pedestrians and cyclists. 70 % of all the transportation in Flemingsberg are going to be by walking, cycling, and public transport by 2030 (Stockholms Läns Landsting et al., 2018). With the existing conditions for transportation that will be difficult to achieve, and in addition the traffic on Huddingevägen is expected to rise from ±30 to ±40 thousand on an average daily mean by 2045 (Tyréns, 2019c). Resulting in fewer opportunities to be a sustainable city, which is a part of the goal for 2030 (Stockholms Läns Landsting et al., 2018).

As the project area is designed today it is not a coherent and lively city, and there's not a reason for people to go there for more running errands. There is no clear meeting point that creates a socially cohesive centre (Stockholms Läns Landsting et al., 2018). Nor does the area offer many leisure activities, the only existing ones are Flemingshallen, the library and the centrum mall. To not further develop the area would make it difficult to reach the goal of a living city (ibid.).

3.4 Plus Alternative

The Plus Alternative considers changes in scale in the planned project. The Plus Alternative will imply a reduction of the planned project area with 15 %, which is the exclusion of Phase 5 and the northern corner of Phase 2 (see Figure 39). The area of Phase 5 (approximately 7.5 ha) is characterized by unexploited natural areas, in close proximity to the Flemingsbergsskogen nature reserve. The northern corner of Phase 2 (approximately 3.5 ha) is also characterized by natural areas but a part of it is exploited with a graveled pitch. The Plus Alternative aims to reduce the pressure that the planned project has on biodiversity and the water recipient lake Orlången. The suggested alternative will still meet the vision aim with 35 000 workers and 5 000 accommodations by year 2050 in the project area (Huddinge kommun, 2019a) by constructing taller buildings.

The plan program stipulates that the number of storeys for each building in the development area varies between 20 and 30 storeys (Huddinge kommun, 2019a). One single storey has a height of three metres and the buildings' height will reach up to 60 metres in the residential areas (Gregorsson, 2019. Personal correspondence). With the Plus Alternative around 15 small-scale apartment buildings from Phase 5 and the northern corner of Phase 2 will have to be added on top of the planned buildings in the other phases. The resulting additional height cannot be derived yet, as detailed plans will follow.

As explained by Sofia Gregorsson from Huddinge Municipality, a different location is not being taken into account, as government documents highlight the importance of a development area in Flemingsberg (Gregorsson, 2019. Personal correspondence). Therefore, changes of location were not considered by the developer.

The following section will predict and evaluate the impacts caused by the Plus Alternative, with a focus on the effects connected to the conservation of natural areas and the construction of taller buildings. Therefore, not all indicators from the planned project are included, since most impacts stay unchanged in the Plus Alternative. The temporal boundaries will be the same as defined in the planned project, by not exploiting the area of Phase 5 and the northern corner of Phase 2, the planned construction in these areas will be relocated within the area of the other phase, which will lead to a change of the spatial boundaries.

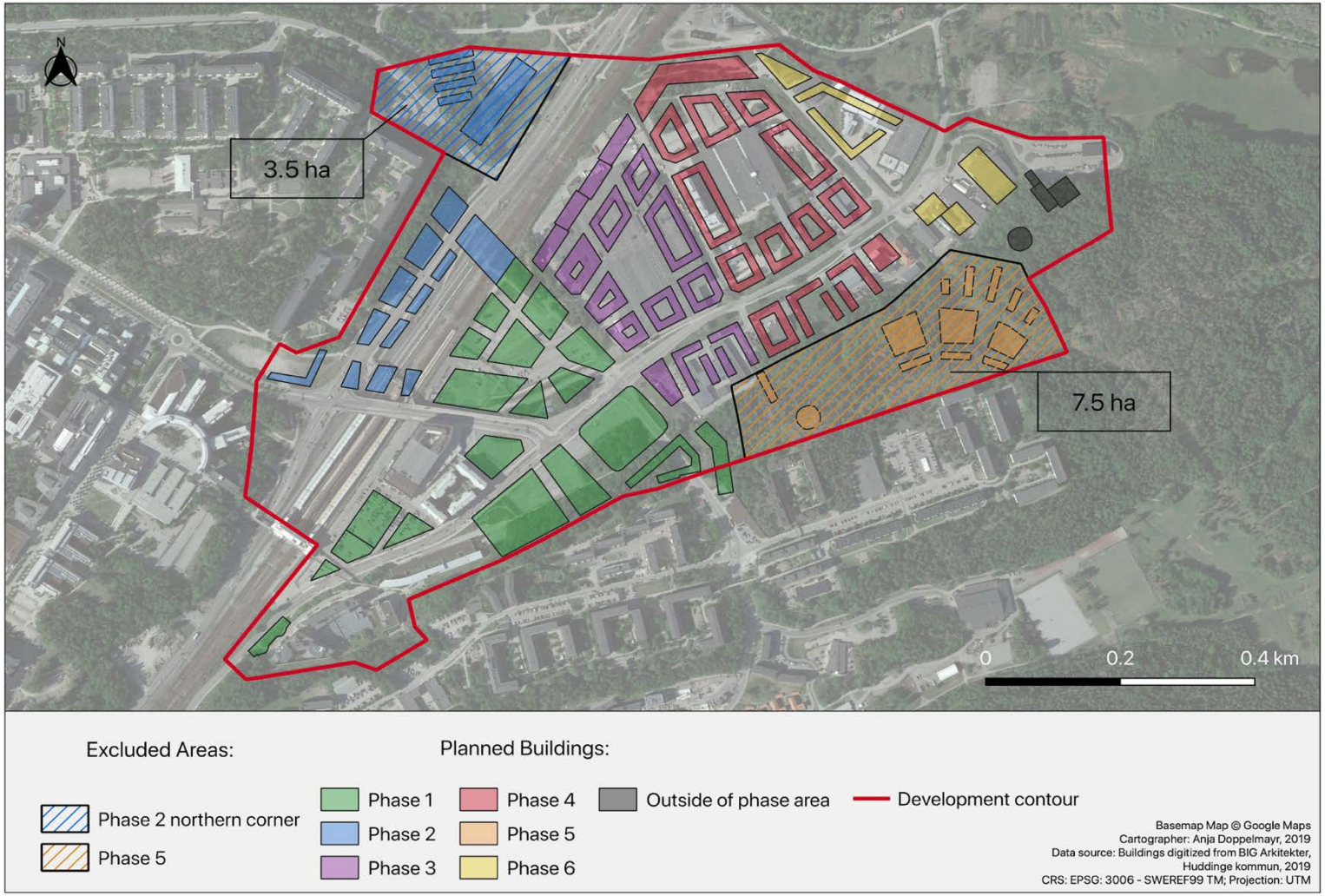


Figure 39. *Planned project area for the Plus Alternative excluding Phase 5 and northern corner of Phase 2. (BIG Arkitekt, Google Maps. Illustrated by Anja. Doppelmayr, 2019)*

3.4.1 Natural Environment

Biodiversity

In the Plus Alternative, the currently unused parts of the project area, the forest in Phase 5 and the green area in the northern corner of Phase 2, are left unexploited. That would mean this project would not intervene on the habitats in the green wedge Hanvedenkilen. This composes a prominent difference in impact on biodiversity compared to the planned project, as the species in these areas are left undisturbed, instead of being removed permanently by the excavation and sealing of surfaces.

The light pollution in the area would increase, as mentioned in Section: 3.1.3 *Phase 3-4: Residence Area* subchapter *Light pollution*, but there is no expected difference between the Plus Alternative and the planned project. During the construction phase, the biodiversity will still be affected by noise. It is expected that the noise level will increase somewhat between the present situation and the operation phase of the planned project (Huddinge kommun, 2019a), which is assumed to also be true for the Plus Alternative (see Section: 3.4.1.5 *Noise* below). It is, however, uncertain if this increase would influence the biodiversity.

Compared to the perceived design of the park in the project plan program, where the park is dominated by green areas (Huddinge kommun, 2019a), the preserved forest would presumably absorb more pollutants than the park, because of the larger quantity and size of the trees (Paoletti et al., 2011).

In summary, the impact on biodiversity of the Plus Alternative would be minorly adverse compared to the baseline, because of the factors mentioned in the biodiversity subsections in the Sections: 3.1.1 *Phase 1: City Centre* and 3.1.3 *Phase 3-4: Residence Area* respectively. The factors left unmentioned here are considered unchanged from the project plan.

Air Quality

In comparison with the planned project the Plus Alternative will have a smaller exploited geographical scale, but the smaller area will be compensated by taller buildings to keep the same number of planned apartments. Impacts during the construction of new infrastructure, movement of land, demolition of buildings and exploitation of unused areas, are only for a short period of time and are assumed to have the same impact on the air quality as the planned project. The significance is therefore minor adverse.

Air pollution that becomes trapped between buildings in high-rise, dense cities, has become a major problem in recent years. Specifically, geometric parameters, such as building density and height, affect the ventilation within an urban area. This can hinder the air flow through an area and lead to higher concentrations of air pollution in cities (Kristóf and Füle, 2017). With the Plus Alternative, the city will become even more dense than the planned project. According to Cárdenas Rodríguez *et al.* (2015), a compact city with a dense population often has problems with high concentrations of SO_2, which can greatly affect the air quality. However, a city with a denser layout can also have a more efficient infrastructure, due to the reduced reliance on roads and more efficient public transport, which could lead to lower emission levels. During the operational phase, in comparison to the planned project, there is still a neglectable impact on air quality if public facilities, commercial buildings, residential buildings and sealed surfaces are evaluated individually, but may have a significant impact when evaluated together.

Compared with the planned project, the buildings must be taller to compensate for not exploiting Phase 5 and the northern corner of Phase 2. It is difficult to predict how a taller city could impact the air quality because it depends on several different factors, such as; the physical urban structure, the amount of traffic and the air filtration efficiency of urban vegetation. With the Plus Alternative, more green areas (in the less densely populated phases) will be preserved, which could improve the air quality for the outer parts of the project area, but the air quality is expected to remain the same (as the planned project) in the denser areas. Therefore, it is assumed that there will probably not be a significant difference between the air quality of planned project and the Plus Alternative, and as such, the significance is minor adverse.

Surface water

The major difference in the effect of the Plus Alternative on surface water as compared to the Planned Project is that there will be less sealed surfaces. If the exploitation decreases by 15 %, around 10 ha will be left as surfaces that can infiltrate water, which will lead to the generation of less runoff. The recipient lake Orlången receives all the stormwater that is generated within the project area through a wetland-complex. According to Structor (2019), if the complex experiences a significant increase in precipitation, the water will not be able to be properly filtered in the future, if the complex maintains its current design. The wetland-complex has an invaluable function by being an ecosystem service, which has the ability to support biological productivity and biodiversity, flood regulation and improve water quality (Thorslund et al., 2017). In order to avoid the destruction of the wetland-complex, an ambitious stormwater handling system will be a cost-beneficial solution for the developer and the Municipality. By increasing the proportion of infiltration surfaces within the project area, the wetland-complex will have a better chance at facing meeting future challenges. Therefore, the Plus Alternative is considered to have a minor beneficial impact on the surface water. However, the Plus Alternative will still need ambitious stormwater solutions as suggested the mitigation section to achieve the environmental quality standards and adequate climate change adaptation for lake Orlången. The other actions are considered to have the same effect on the indicators in the Plus Alternative as in the planned project.

Groundwater

The groundwater will be affected in a similar way to the planned project in the construction and operational phase. The only difference is that the Plus Alternative will have a positive effect on the groundwater quality because that resource is not exploited in Phase 5 or the northern corner of Phase 2. This leads to more areas having a greater infiltration capacity, which enables the generation of more groundwater than previously planned. Therefore, the action of sealing sealing surfaces in the operational phase is considered having a minor beneficial effect on groundwater, when compared to the planned project, where it is considered having a major adverse effect.

Noise

As pointed out in the impact assessment of Phase 5-6, the impacts of noise pollution, especially during the construction work in Phase 5, could have a negative impact on the fauna and Phases 1, 3, 4 and 6, which are located alongside the current forest area of Phase 5. Thus, if Phase 5 is left unspoiled and under the assumption that the latter phases would be built before Phase 5, additional noise pollution of adjacent areas during construction of this phase would be avoided. Significant changes to the overall development area can not be expected. The construction of the

northern corner of Phase 2 would similarly have an effect on the adjacent apartment buildings, which would be avoided by leaving the area unspoilt. The preservation of these two areas could contribute positively to the overall noise pollution of the whole development area. In conclusion the impacts on noise will remain the same as for the planned project.

The preserved areas would have a minor beneficial effect for the fauna and well-being of humans, both during construction and operation of nearby phases, if compared to the planned proposition. First, as argued in the impact assessment of Phase 2 (Section: 3.1.2.1 *Natural Environment,* subchapter *Noise)*, the northern corner of Phase 2 would have been affected by noise levels up to 70-75 dBA, wherefore additional noise reduction measures would be necessary. Compared to the planned project, the Plus Alternative would improve the strategic placement of the buildings, especially residencies in the northern corner of Phase 2 with respect to noise generation. As the concern, which was mentioned in the impact assessment of Phase 2 (Section: 3.1.2.1 *Natural Environment,* subchapter *Noise)*, regarding the channeling of noise at the tunnel openings due to the overlay, can be avoided.

Secondly, as natural, vegetated areas and soft surfaces function as noise absorbents (Huddinge kommun, 2019a; Boverket, 2017), the forest area in Phase 5 will dampen or muffle sounds that could otherwise travel during the construction and operation phases. Parks and urban forests can decrease noise levels and affect traffic noise distribution (Kropp et al., 2016).

Nonetheless, the Plus Alternative would imply an increase in the height of the residential buildings, in order to fulfill the project's aims and meet the amount of apartments that are planned, without compromising the amount of "natural" areas in the project. This will be solved by adding more floors to each of the buildings that are planned. Screening or reflection of sound from terrain/sealed surfaces and buildings can directly expose higher floors (particularly in buildings greater than/equal to 60 meters high) to high levels of noise (Ögren and Barregard, 2016). As the area covered by sealed surfaces will not decrease greatly, these areas will still contribute to noise pollution similarly to the planned project. The resulting noise reflection depicted in Figure 40, which shows that the layout of an urban area can still have a great impact on the upper floors of a tall building, through the so called "canyon effect" (Sanchez et al., 2015).

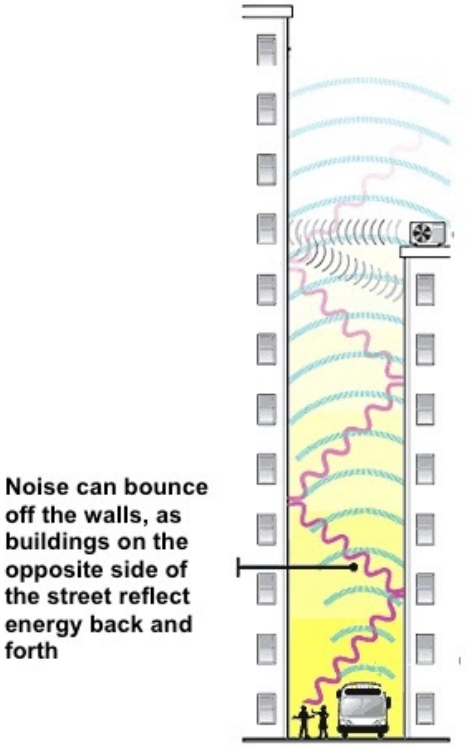


Figure 40. *Canyon effect: Noise reflection due to traffic and densely built urban areas (Swanson, 2004, designed by McKibillo. Adapted by the authors.).*

The height of buildings, in general, apart from other factors like building density, surrounding building characteristics and façade material, can have a significant impact on noise distribution, which must be investigated further (Kim et al., 2017; Wang et al., 2019). In particular, the impact of traffic on noise distribution on buildings.

Soil

The impacts on soil are mostly unchanged from the planned project. The soil will, however, not be excavated or in other ways affected in the excluded areas, which means that the soil biodiversity and soil organic carbon remains. Because of this, the preserved carbon will stay in the ground, instead of risk being returned to the atmosphere as carbon dioxide (CO_2). When the project area is scaled down, the soil will presumably be less affected by heavy metals and other pollutants from the traffic, since no roads will be constructed in these areas. If the soil is contaminated, it is sometimes beneficial that the pollutants stay put, instead of being resurfaced and relocated during the excavation.

3.4.2 Cultural Environment

Cultural Heritage

With the Plus Alternative, the northern parts of Phase 2 and Phase 5 will be left untouched in comparison to the planned project. This means that the surrounding areas close to Grantorp will not be included, and therefore, unchanged. Overall, the significant impacts are assumed to be the same as for the planned project regarding the cultural heritage.

Visual Landscape

The big difference in the visual landscape between the planned project and the Plus Alternative is that the city will be higher but in a smaller geographical area. During the construction phase the significance is the same as for planned project, minor adverse.

Phase 5 will not be exploited and people living in Phase 3-4 and 6, closest to the nature reserve will have a greener view which could have a positive

impact on those who are living there. Compared with the planned project the visual landscape will be characterized by even taller buildings and depending on the construction, the city could be even denser depending on construction strategies. This could have an affect on people's view from their homes. The overall character for this area is still a high and dense city and therefore the difference compared with the planned project will not be major. It is therefore assumed that the significance is the same as for the planned project. The significance for public facilities, commercial, and residential buildings will major beneficial. Parks and green spaces are assumed to have major beneficial impacts on this area because of the preservation of the forest area and the green areas in the northern corner of Phase 2.

3.4.3 Socio-Economic Environment

Housing

The overall construction of buildings will not change tremendously compared to the planned project. The relocation of houses will not affect the construction work, therefore there is no different effect expected during the construction phase of the Plus Alternative compared to the planned project.

As the same number of apartments are planned to be built, but those in Phase 5 and in the northern corner of Phase 2 will be relocated, the operational impacts residential buildings on housing remain the same as for the planned project. A possible effect concerns the rental prices of multi-storey apartments with better views. Whereas higher rental prices could be suspected for taller residential and mixed-use buildings, Larcombe et al. (2019) argue that a broad range of high-rise apartment complexes are less expensive for developers and thus rental prices are not expected to rise. The authors proceed: “For this reason, high-rise apartments are increasingly preferred by government agencies providing housing for socially disadvantaged people” (ibid.). As regards the public and commercial buildings, the impacts on housing will remain similar to the Planned Project.

The Plus Alternative suggests the preservation of nature and thus leaving the forest area of Phase 5 and the open area in the northern corner of Phase 2 unexploited. Parks and open spaces, which will gain in size, distribution and natural value can contribute to the attractiveness of the planned apartments. Close proximity to unspoilt nature can thus have a minor beneficial impact on the housing situation in Flemingsbergsdalen.

Recreation

In the Plus Alternative, Visättra Stadsdelspark which is one planned park of three, is removed, and instead the current forest is preserved. Because of this, the form of recreation for the project area is changed. Instead of being a multipurpose functioning park, with open spaces for play, sports, and meeting other people, the forest area in Phase 5 could be used for recreational use in form of stress relief, dog walks, running and picking mushrooms and berries for example. The forest is currently not made accessible for people with disabilities, which in the Plus Alternative, would mean that the area would either remain inaccessible for part of the population in the area, or that measures are needed to prevent this. Since the sealed area is smaller and the green structure area is larger in the Plus Alternative, the stress relieving effect on the inhabitants of the area might increase slightly (Haq, 2011). Parts of the area in the northern corner of Phase 2 are today gravelled surfaces, and it would be interesting to investigate if this area could be claimed by the adjacent allotment

organisation, using elevated flower beds for urban agriculture. This would increase the recreational value in that particular area. Most of the factors are unchanged from the Planned Project, the discussed factor is “parks and green spaces”. In comparison to the current situation the recreational aspects are majorly beneficial, and unchanged from the Planned Project.

Health

During the construction phase there will still be the same procedures as for the planned project which means that the air quality will be affected and the noise level will be louder compared with the baseline. The construction is only for a short period of time until the site is completed. The construction time will probably be the same as for the planned project. It is therefore assumed that there is not a big difference in the impacts on humans’ health compared with the planned project and the significance will still be minor adverse for human health, see impacts assessment for planned project.

In comparison with the planned project there will be more people living in the same space due to the smaller scale and taller buildings, this could cause an increase in noise level, see Section: 3.4 *Plus Alternative* subsection *Noise*. As mentioned above, a smaller scale city could be beneficial for sustainable transportation in the city and thereby improve the air quality. But the air quality also depends on the building design and if pollutants are trapped in the city or not. With the Plus Alternative the buildings will be even higher than in the planned project and this could create bigger shadows and less sunlight, which could affect human health even more in comparison with the planned project.
A more natural environment, such as one with green spaces within the urban areas have beneficial impact on stress relief on people, in comparison with people living in urban areas without access to natural environment. People who spend more time outdoors have shown a lower stress level and an improved physical health (Haq, 2011). For the Plus Alternative the forest area will be closer to the residential area which could have positive impacts on human health. The impacts on human health for the Plus Alternative is assumed to be more or less the same as the planned project, it depends on how the city will be structured and what kind of transportation will be mainly used in this area in the future. The significance is therefore assumed to be the same as for the planned project, which are major beneficial because of the new services, housing areas and recreational activities that will be built in the area compared with the baseline.

Safety

Impacts on safety, in general, will not differ greatly from the planned project. Thus, the impacts are expected to have the same significance. Two points need to be highlighted, however. Tall buildings are in need of adequate fire safety strategies, and fire safety needs to be addressed and discussed within the detailed plan processes (Cowlard et al., 2013).

In regard to the preservation of the forest in Phase 5, it should be said that the residents’ perception of safety during night times could decrease. If the forest area is not illuminated, this part of the development area could potentially have a negative effect on the level of fear and increase discomfort.

Employment

Effects on employment due to the Plus Alternative are not differentiating from the planned development. However, it should be mentioned that there is a limited number of qualified engineers working with buildings as

tall as 25-30 metres (Eriksson, 2019. Personal correspondence). Thus, special knowledge regarding the construction of buildings, which are planned to rise up to 90 metres in Phase 1 and up to 60 metres and above in the residential areas will be required. Overall, the impacts on employment can however be assessed in analogy to the planned project.

Accessibility and Connectivity

The conservation of Phase 5 and the corner of Phase 2 are not expected to affect the accessibility and connectivity of the area differently from the planned project. This is due to the fact that these areas are located on the outskirts of the project area. One is adjacent to an already existing housing area, and the other is a graveled pitch facing Huddingevägen, the railway, and a few green areas.

Table 11. *How different indicators will be affected by different actions taken for the Plus Alternative. The striped cells indicate a change in impact as compared. to the Planned Project Alternative.*

		Construction Phase				Operation Phase						
	Actions / Environmental Indicators	Construction of infrastructure	Movement of land	Demolition of buildings and removal of infrastructure	Exploiting unused areas	Public facilities	Commercial buildings	Residential buildings	Waste generation	Sealed surfaces	Traffic	Parks and green spaces
Natural	Biodiversity	-	-			-	-	-			-	+
	Air (quality)	-	-	-	-	+ / -	+ / -	+ / -			- -	+ +
	Surface water	- -	- -	- -	- -	+	+	+		+	- -	+ +
	Ground water	- -	- -	- -	-					+	-	+
	Noise	-	-	-	-					-	- -	+ +
	Soil	-	- -		-						- -	- -
Cultural	Cultural heritage	- -	- -	- -	-						-	-
	Visual landscape	-	-	-	-	+ +	+ +	+ +				+ +
Socio-Economic	Housing	-	-	-		+ +	+ +	+ +				+
	Recreation	-	-	-	-	+ +	+ +	+ +		+ +		+ +
	Health	-	-	-	-	+ +	+ +	+ +		+ / -	+ + / -	+ +
	Safety	-	-	-	-	+ +	+ +	+ +			+ + / -	+
	Equality					+ +	+ +	+ +			+	+
	Employment	+	+	+		+	+ +				+	
	Accessibility and Connectivity	-	-	-	-	+ +	+ +			+ +	+ +	+

4. Mitigation Measures

One of the key objectives of an EIA is to ensure that the objectives of the proposed development are met with no or minimal negative impact to the receiving physical, social, economic and cultural environments. This objective is achieved through the identification of measures which avoid, minimise and reduce impacts. In cases where all the aforementioned measures do not work, methods used to offset or compensate for impacts are considered as a last resort (IEMA, 2004). Mitigation measures are often included in the project planning stages, in response to the anticipated adverse impacts (IEMA, 2004; Glasson et al., 2012).

In this section, mitigation measures are recommended for both minor and major adverse impacts on various indicators that may arise during the project's construction and operation phases.

These recommendations will focus on mitigation measures that will:

- completely prevent the impacts from occurring;
- ensure that there will be minimal damage from impacts that cannot be completely avoided; and
- reduce the scale and magnitude of impacts through adoption of best practice management measures.

Based on the evaluation of impacts in previous sections, the mitigation measures for significant impacts have been identified and explained, below. However, the impacts on visual landscape, recreation, accessibility and connectivity have undergone assessment and have been categorised to be of low priority (having minor adverse impacts); it is assumed that best practice standards will be implemented in order to further minimise their impacts, therefore, they will not be mentioned further.

4.1 Noise

Noise has been identified as *"the second largest environmental risk to public health after air pollution"* by the World Health Organisation (WHO). This declaration may be attributed to the challenges of mitigating noise impacts, especially if noise pollution originates from many diffuse sources, such as traffic, construction activities, or large crowds within in a given area, for example, during music concerts or sporting events (Glasson *et al*., 2012). Major sources of environmental noise in Sweden, and in particular interest for this development, are: traffic, railways and construction sites (Eriksson *et al.*, 2013). It is impossible to completely avoid noise emissions during the construction phase. The majority of the construction activities only minorly adversely impact noise; therefore, it is crucial that the specific guidelines for noise levels from the Swedish Environmental Protection Agency be followed, to ensure that noise pollution is adequately restricted. During construction, the noise that can be a nuisance to people residing in the vicinity of the development can be minimised by executing construction works during the day or restricting the operation times of noise emitting machinery (Strömberg, 2011) to 07:00 to 19:00, as suggested by Naturvårdsverket (2019d).

The guidelines for noise levels in Appendix 3 Table 1 must be followed during the construction phase. The construction of the railway station's overlay may be able to lower noise levels to a certain extent, as it will function as a noise barrier to buildings in close proximity to the station. However, there are still concerns with regards to the surrounding areas where the tunnel opens, concentrating and increasing noise levels in the

given area. Further research is required regarding specific noise prevention measures for potentially elevated levels near the tunnel opening, and the overlay's impact on noise pollution reduction. In 2013, noise levels in and around the project area exceeded the levels found in the noise guidelines due to traffic along Huddingevägen and the railway (Tyréns 2019b). Therefore, the expansion of the high-speed railway will require the installation of noise barriers in order to reduce noise levels (Tyréns 2019b).

Noise reduction can be tackled at the source using mechanical, acoustic and organisational methods (Strömberg, 2011). Source control, one of the most reliable and preferred methods, seeks to eliminate noise from the source before it can be emitted and reach receptors (Thalheimer, 2000). Should source controls be ineffective, then other methods, such as path controls and receptor controls should be used, although these are often cost-prohibitive (Thalheimer, 2000; Strömberg, 2011).

Noise generation can be reduced by having temporary walls made of different materials, which will act as noise barriers around the construction site (Strömberg, 2011). This enclosure will control and lower noise between the source and the receptor. Construction workers will be exposed to high noise levels during construction, which could compromise their hearing in the long term. For this reason, protective gear such as headsets or earplugs must be used at all times, in order to reduce exposure to unacceptable noise levels. The use of earplugs or headsets will reduce noise levels by up to 30 dBA and keep them within permissible limits (Strömberg, 2011). Construction machinery and equipment should be maintained regularly because equipment malfunction can cause excess noise to be emitted. In addition, other noise mitigation methods which are inexpensive, easy to implement and manageable during construction include careful placement of noise sources away from hard reflective surfaces, as they are known to amplify sound levels. Construction of acoustics which involve new and traditional sound-proofing systems can be used by sports, events and cultural centres in the evenings, in order to reduce noise. This will minimise annoyance, stress levels and other associated medical conditions of the residents located in close proximity to these services.

Traffic related noise and vibrations from are becoming a major concern in urban areas, as they can negatively affect building structure and sensitive equipment in laboratories, hospitals and offices, as well as threaten the health of inhabitants (WHO, 2011; Wersäll et al., 2012). A given building's structural design may make it sensitive to vibrations, which could prove to be potentially hazardous. Vibrations can also be generated by the heavy machinery used in construction (Strömberg, 2011). This can be reduced through adequate maintenance, minimising the use of machines with vibrating effects simultaneously with vibration isolators which block the transmission of vibrations into the ground.

4.2 Air Quality

A major source of air pollution in Sweden, particularly in urban areas is road traffic (Naturvårdsverkets, 2019e), therefore it is of particular interest for this development. Motor vehicles contribute to air pollution by emitting NO_2, particulate matter and other organic compounds which promote the formation of ground-level ozone. To promote cleaner energy and improve air quality in the city, the proposed project development advocates for the use of urban public transportation, instead of private motor vehicles. One of the 16 Swedish environmental objectives is to have clean air by the year 2020; although it is not feasible to reach this goal by 2020 (Naturvårdsverkets, 2019e), it is still critical to continuously strive to find the means to achieve it. Air quality policies and guidelines that focus on

reducing pollutant emissions from the source, position the source as far as possible from the receptors and then, consider complementary methods, such as green infrastructure (GI) (which includes green roofs, hedges, parks, street, trees etc.), can be beneficial to air quality by reducing human exposure to polluted air (Berardi et al., 2014; Abhijith et al., 2017; Hewitt et al., 2019).

The proposed development will have city streets with significant space for cars, bicycles and pedestrian traffic. In order to minimise human exposure to motor vehicle pollution, it is recommended that hedges between city streets (source of pollutants) and pedestrian pathways (receptor zones) be placed in parallel to each other. The introduction of hedges (as barriers) will force the pollutants to rise, which increases the path length that the pollutant must travel before reaching the receptor (see Figure 41) (Abhijith *et al*., 2017; Hewitt *et al*., 2019). This facilitates the dilution of the pollutant and reduces the concentration of pollutants along pedestrian pathways or sidewalks.

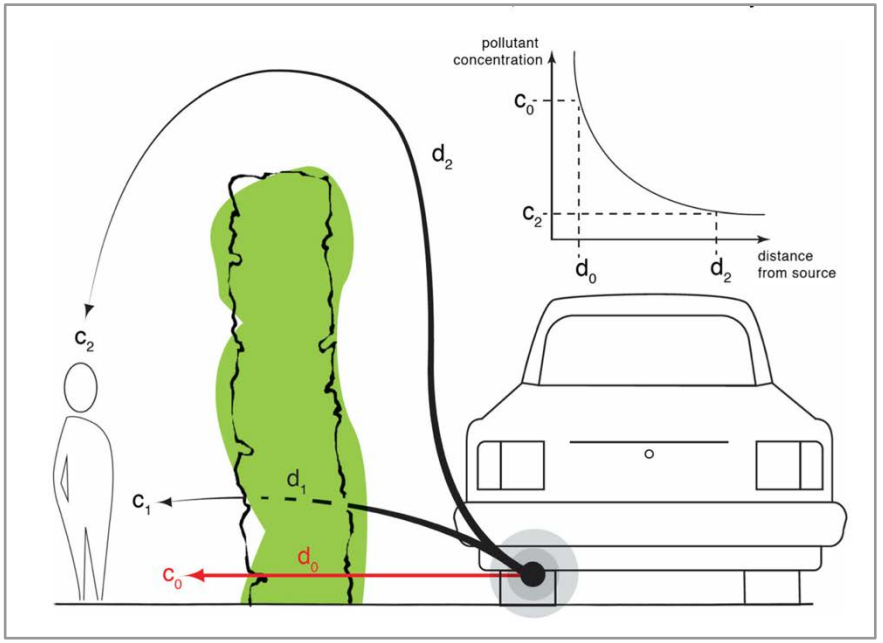


Figure 41. *Effect of a permeable linear barrier or hedge on pollutant concentrations. The pollutant concentration experienced by the child receptor is the mass-weighted average of the concentrations through (**c_1**) and over (**c_2**) the linear barrier. Along paths **d_1** and **d_2**, pollutant concentrations are diluted by mixing and deposition. In the absence of the linear barrier, the receptor experiences higher concentration, **c**, diluted over shorter distance, **d**, and not subject to enhanced deposition to vegetation (Hewitt et al., 2019).*

Construction activities such as the demolition of infrastructure, for example, the anticipated demolition of Huddingevägen before it is lowered, may lead to elevated concentrations of dust and particulate matter within the project area. It is worth noting that the emission rates of these pollutants are dependant on the type of activity and weather conditions. It is therefore recommended that construction activities involving excavation

and demolition should be undertaken on days with no or minimal wind speed, in order to minimise deposition potential and reduce the spatial extent of the area that will be affected by these pollutants. Minimal dust deposition can be achieved by constantly monitoring weather conditions and planning a flexible work program, which pays attention to dry and windy conditions (Xing *et al.*, 2018). Exposed surface areas should be sprayed down with water to suppress dust particles in order to prevent them from becoming airborne (Zuo *et al.*, 2017; Xing *et al*., 2018). However, this should not be the main method for suppressing dust as it may cause excess water use. During construction, site inspections, data collection and monitoring of dust and air quality should be implemented, to ensure that air quality remains within the specified guidelines. Exposed and disturbed areas must be covered during periods of no construction until such activities are resumed, sealed or revegetated immediately upon completion of construction. When the aforementioned dust management measures are implemented, it is quite unlikely that the construction activities will emit pollutants that will exceed the air quality guidelines.

4.3 Soil

Based on the assessment, the impacts produced by the construction and operation of the proposed project on soil mainly includes the original composition of soil, potential erosion, the permeability of the soil and soil pollution. As water infiltrates and flows through soil, these two environmental elements are always linked closely and have frequent interactions. The water content of the soil is dependent on the permeability, which may be affected by sealing. Heavy rainfall and runoff may cause detachment and transport of soil, then erosion (Gilley, 2005). Water erosion of the soil may lead to pollution of the natural waters due to the sediments in the flow, such as off-site siltation of waterways and reservoirs (Lal, 1998). Meanwhile, the contaminants in the soil are also severe pollution to the water through the transportation of infiltration flow. As mentioned in the impact assessment, the soil in the project area was polluted by the previous industrial, with contaminants that can't be neglected. Therefore, water needs to be considered as well when carrying out the following mitigation measures for the impacts on soil.

4.4 Biodiversity

The biodiversity has been identified as a factor that will be adversely affected during both the construction and operation phase of the project. If the project will proceed according to the present plan, the forested area in Phase 5 will be removed and this implicates that the biodiversity in the area also will be removed from the area. One mitigation strategy to allow for different species to migrate to the nature reserve, prior to the removal, is to ensure that the construction close to the forest and deforestation and removal of vegetation occurs when the inhabitants of the forest are more mobile. One mitigation strategy can be to start with disturbing activities and deforestation during autumn before insects and other animals go into hibernation and therefore can move away from disturbing activities. It is also important to consider an appropriate time with respect to nesting birds and other animals. These species need to be strong enough to survive without their nests and dens and be able to migrate to the nature reserve (or elsewhere).

A mitigation strategy to improve the biodiversity in Flemingsbergsdalen is to have connections between the plantations, parks and other green areas to allow movement of species between these areas. Green corridors can also be favorable to allow species from the nature reserve to recolonise the

area. Green roofs are important and can improve the biodiversity in the area.

To prevent any additional load of phosphorus and nitrogen to the already over eutrophicated Orlången, it is recommended that any fertilising of green roofs-, and areas and parks are heavily limited during operational phases. One alternative, which mitigates the transport of excess nutrients, is planting perennial nitrogen fixating plants on the roofs and in parks; trees, shrubs and vines, which are also beneficial for pollinators and insects. Apart from preventing over fertilisation, by binding the nitrogen in the plant instead of letting it leach out into the water and onward to the wetland, these plants can act as noise reducers, if allowed to clench and cover the facade of buildings.

Different types of nesting boxes are important to make the region attractive for birds and insects. Organised feeding of birds can be suggested to support them when their natural habitats have been disturbed. Beehives on roofs can be favorable to attract more pollinators to the region. Different types of plants are important for diversity. The same biodiversity will never be able to be recreated but biodiversity can be maintained through the use of many different plants. The choice of vegetation to be used in open ditches and ponds can also be useful. This might even create favorable environments for amphibians and ducks that thrives in these environments.

4.5 Light Pollution

The combined light pollution of the Flemingsbergs project is predicted to have a long-term adverse effect on the surrounding natural environment. The major contributor to the spatial spread of the light are the high buildings located in Phase 2, and the buildings outlining the project area of Phase 5-6. Furthermore, all buildings in all phases will contribute to the sky glow.

Some mitigation measures for light pollution can be applied to all light sources, at all locations. However, in order not to compromise the security and safety of the inhabitants, specific assessment and mitigation measures might be needed in certain areas. There are four main areas of mitigation of light pollution subjected to evaluation (Jägerbrand, 2018).

Prevent and Limit that New or Unwanted Areas are Illuminated

In urban environments, the ecological impact is enhanced whenever a natural environment is intermixed into the inhabited area, e.g. whenever habitat fragmentation occurs and light is spread over larger areas due to edge zone effects. Mitigation measures could therefore be to avoid fragmentation of natural environments, by keeping large areas of greenery isolated and undisturbed. Adding buffer zones; zones that are not sensitive to light, that does not require illumination for human purposes and are also not high value areas for flora and fauna, could act as a green boundary, minimizing the light pollution of surrounding green areas.

Restrict the Extent to which a Light Source Illuminates its Surrounding

Some areas are required to be illuminated even though they are located in close vicinity to nature environments, such as walking-, and bicycling paths, that either cross or outline nature areas. The extent to which a light source illuminates its surrounding can be restricted by assessing the purpose of illumination, and using alternative designs (Jignesh, 2019; Figure 42). The height of the streetlight could also be shortened to hinder the light to

spread outside of the intended area of illumination (Jägerbrand, 2018). Greenery covering the light source could also act as an additional coverage to limit the spread of lights i.e. tall trees exceeding the height of the street lights, or surrounding stores and offices located on the ground floor.

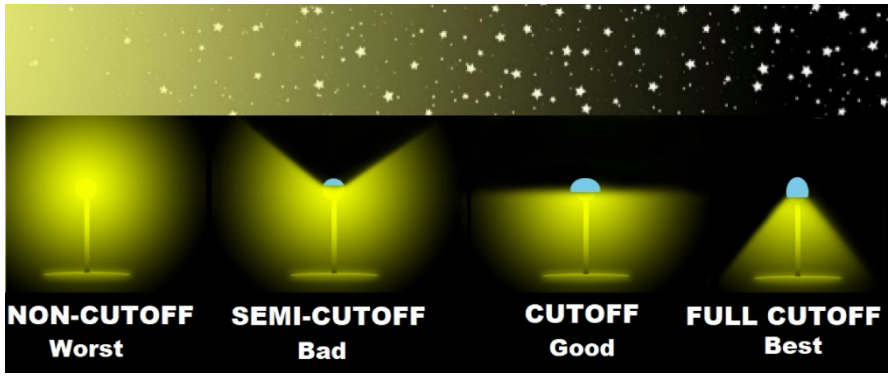


Figure 42. *How cut-off design can alter the spatial spread of light (Jignesh, 2019).*

Limit the Time of Day when Illumination needs to Occur

There is a conflict of interest in assessing which time of day the illumination is needed versus when it has adverse effects, as it is during the dark hours it poses harm on natural surroundings, whereas the illumination is needed in the populated areas during the dark hours. However, turning off lights in commercial and office buildings could contribute to the decrease in unwanted illumination and sky glow (Jägerbrand, 2018). Despite this already being implemented in many areas today, additional measures could be to turn off the light even sooner as compared today. Mitigation suggestions include conducting surveys of when the illumination of offices need to take place, when the light may be turned off, and installing central shut off systems in big building complexes which are regulated either by time or availability of natural daylight. The use of movement detectors can also be useful so that the lights only shine when people are there.

Limit the Light Intensity of the Illumination

As we replace conventional street lighting with light-emitting diode (LED) lights, society is moving towards a more energy-efficient development. However, the LED light cast light in lower wavelengths compared to conventional lamps (Figure 43).



Figure 43. *Different wavelengths generate different color light. The bluer light to the right has a bigger impact on animals' circadian rhythm (Wyatt, 2013).*

Additional measurements could be adapting both the intensity and wavelength of the illumination based on its purpose. For example, reducing the amount of blue light generated by the LED lamps, as this is the light associated with daylight and disturbs the circadian of animals. However, thresholds for blue light does not exist, and the precautionary principle should be applied (Jägerbrand, 2018).

4.6 Stormwater

As seen in Table 10 and described in Section: 1.2 *Summary of Impact Assessment* it is possible to see that the project is likely to have minor to major adverse effects on the groundwater and surface water. Therefore, the handling and treatment of stormwater is important to mitigate potential negative effects on surface water as well as on groundwater. This is important to consider both during the construction phase and the operational phase of the project.

Mitigation during the Construction Phase

The choice of materials for the construction is important, both for the roofing, facades, equipment, etc. to mention a few different areas where active choices can be made to minimise the spread of contaminants by the stormwater and prevent contamination of the groundwater. The handling and treatment of stormwater early in the construction phase is of importance as negative impacts on the surface water as well as groundwater have been identified especially under the construction phase. The sedimentation pond must be constructed early in the construction phase or apply other preliminary solutions and/or additional treatment of drainage water from the construction sites to mitigate potential negative effects.

Multi Functional Surfaces and Green Solutions

The sealing of surfaces has been identified to have a minor to a major adverse effect on the surface water and groundwater and has been identified as an issue in the impact assessment. A possible way to mitigate this is to make use of different green solutions. Green solutions are important mitigation strategies and also useful to consider in the design of parks and recreational environments.

One suggestion to mitigate the risk of floods in the project area is to increase the infiltration possibilities in the city. Increased infiltration capacity will cause a retention in the generation of stormwater and increase the residence time of the water in the project area before it enters the wetland-complex. This is important for purification purposes and to decrease pressure on the wetland-complex and to ensure that the function of the wetland-complex is maintained. This is of importance so that the planned project does not decrease lake Orlångens chances to meet its environmental quality standards by 2021 and 2027.

A suggestion is that stormwater is handled using open solutions so that the response to precipitation is slower and purification of the water occurs close to the source. It is good if these surfaces are dimensioned to handle large amounts of stormwater, preferably with a climatic factor in mind (see Chapter 5: *Cumulative Effects*). Open ditches and swales (svackdiken *sv.*) generally have a delaying effect on the residence time of water and is favorable for sedimentation (Larm, 2000). Vegetated ditches are especially good for mitigation as these have a purification effect on the water (ibid.). This mitigation technique might also be an attractive element in the new quarters with many green elements. It can improve the visual appearance of the city, improve the air quality and decrease the noise pollution in the area. The use of open ditches and swales might even improve the biodiversity in the areas, by connecting the different parks and other green spaces. The ditches in combination with the parks with multifunctional areas will have the ability to receive a lot of water. A slow and controlled flow towards the sedimentation pond allows the settling of particles and sedimentation is important for purification (Larm, 2000). As suggested by

Structor (2019) the water can be lead trough stormwater pipes or by open solutions to the sedimentation pond and from the pond to the connection to Flemingsbergsvikens wetland-complex. Large squares can also be constructed to have a multifunctional purpose to be able to collect water at intense precipitation events, to prevent roads and buildings to be flooded (ibid.). To improve stormwater management it is important to adjust the levels of the streets and sealed surfaces to be able to lead the stormwater to appropriate places where the water can infiltrate.

Plantations with bushes and trees and the use of plantations alongside impermeable surfaces are suggestions on mitigation. The plantations can stimulate percolation, infiltration and root uptake of water. It is also efficient with so called skeletal soils (skelettjordar *sv.*) that can have a purifying effect on the stormwater (Stockholm Vatten och Avfall, 2019). Skeletal soils are often built up by coarse material that allows high storing and retention capacity of water (ibid.). Water from the paved surfaces can be guided towards the plantations and be distributed by pipes and get filtered by the skeletal soils. Stormwater pipes can be connected to the plantations to divert water if the plantations will start to be saturated and connected to the stormwater system (Uppsala kommun, 2019). As suggested by Structor (2019) all roads should have trees planted or plant beds with drainage towards them. It is important with solutions close to the problem sources, to minimise the pressure at the outlet.

Naturally, some areas are better suitable for parks and infiltration purposes eg. areas with morain (Structor, 2019). It is important to make use of these areas and plan the parks and green spaces there. Based on the plan programme it looks as if this has been taken into consideration, but it is important to stress the importance of the position of the parks with a stormwater aspect in mind for mitigation purposes. Areas with contaminated soil needs to be identified so that infiltration of stormwater occurs in appropriate areas to avoid pollution of the groundwater.

Filter strips (översilningsytor *sv.*) can also be used for mitigation to increase infiltration and improve the stormater situation in the city (Larm, 2000; Stockholm Stad, 2017). The use of infiltration surfaces has shown to decrease the size requirements for stormwater ponds as they give a delayed response to rainfall and increases the root uptake to be efficient (ibid.). Pedestrian walkways, parking lots and driveways can be constructed with special forms of pavers that allow grass to grow through them. The areas will then be paved but without being completely sealed and enable more greens to grow in the city.

Green Roofs

Green roofs are a mitigation measure that is suggested to improve the stormwater handling (European Commission, 2013a). This measure is discussed in the plan program, but it is important to stress the importance of green roofs to be applied to all new buildings to mitigate the negative effects generated by increased amounts of impermeable surfaces. Green roofs with a substrate of 50 mm can reduce the yearly runoff from the roofs by 50 % (Structor, 2019). The esthetic values and biodiversity will be improved by this mitigation measure. Implementing green roofs will also improve the air quality and can also be used to mitigate urban heat (The Conversation, 2019). Different types of sedum plants are commonly used on green roofs, depending on the plant bed design, even other plants and bushes can be grown on roofs (Vinnova, 2017).

Stormwater Pond

The wetland-complex will have to handle stormwater from an additional 5 ha of stormwater after the construction of the overlay. Some minor modifications that will remove some present low points will also add to the 5 ha (Structor, 2019). As stated in the project description and impact assessment, the increase of impermeable surfaces will increase the surface water generation. Based on observations from the field visit the possibilities to expand the wetland seems limited as the wetland would flood adjacent roads. A stormwater pond will therefore be important to mitigate the stress that the project will pose on the wetland-complex. The importance of efficient stormwater management in the project area is indicated by the impact assessment. In fact, the new project has the potential to improve stormwater management by utilising efficient, and preferably, green solutions (Structor, 2019). One of the mitigation techniques that have been suggested in the Flemingsbergsdalen Planprogram is the construction of a stormwater pond in Phase 6 to improve the purification before discharging water enters the wetland.

A stormwater pond will be built in Phase 6 according to the Flemingsbergsdalen Planprogram (Huddinge kommun, 2019a). The dimensioning of the stormwater pond and the connection from the pond to the wetland-complex must be developed in close dialogue together with the developers of the new Trafikförbindelsen Södertörn. This is important as the new motorway will affect the drainage pathway from the project area to the wetland-complex. It is of great importance that the culverts (vägtrummor *sv.*) are dimensionalized correctly to ensure high discharging capacity to prevent problems with flooding. Structor (2019) also emphasises this as it is of importance with mitigation to prevent flooding of houses and other important infrastructure. However, it is not specified when it will be established. According to the impact assessment, major adverse impacts have been identified for both surface water and groundwater. To mitigate the potential major adverse effects, it is stressed that the pond must be constructed early in the development process so that it can collect and purify water during the construction of all phases. It is important to dimentionise the pond so that it can have a high remediation effect independently of intense precipitation events. The slopes of the embankments to the pond can be covered with vegetation, which causes that the purification of the water to increase. Structor (2019) also suggests that it must be accessible for the vehicles that are needed for maintaining the pond.

Mitigation of Sealed Surfaces

Although sealing the surfaces is an unavoidable process during the exploitation of unused area, the developers can take measures to reduce the detrimental impacts of sealing. There are several sustainable methods that could be considered.

To leave the area green around the proposed construction area and avoid damaging the soil can limit the impacts of sealing (European Commission, 2013b). The soil that will not be sealed still keeps in its original composition and has full ecological functions. In order to make the most of its functions, the greenery around the buildings should be taken good care as much as possible.

Sealing materials is essential to the permeability of soil. To reduce surface water runoff and increase groundwater, permeable building materials is a good choice to avoid the block of water exchange within soil caused by sealing. More water can infiltrate the soil through the permeable surfaces in comparison to normal sealed surfaces. Parking areas are especially

suited to be covered with gravel or grass grids, since they are permeable without demand for new drainage system and have negligible effect on the ground (European Commission, 2013b).

Another design to allow more surface water to infiltrate is green infrastructure such as green roof and green wall, which incorporates green spaces. The benefits are not only helpful to avoid high runoff, but also to reduce heat island effect via water evaporation (European Commission, 2013b). Large projects are suited to build green infrastructure (ibid.). And this project consists of several big constructions such as tunnels, overlay and a lot of new buildings, which is exactly suitable and need the participation of green infrastructure. Furthermore, due to its nature of green spaces, green infrastructure also offers habitats for creatures and protects the area's biodiversity in an efficient way (ibid.).

Consideration of Timing of Development

Time should be taken into consideration when excavation work is to be carried out. It is of great importance to avoid precipitation events, since water is a factor that may cause both erosion and the spread of soil contaminants. So a good excavation plan should include what to do if the work is delayed due to rain (Nassichuk, 2015).

During the excavation, large areas of soil are exposed to the air. When unprotected soil is hit by heavy rainfall, it is easy for water erosion to occur as a primary contributor of sediment formation (ibid.). The soil particles settle in the surface water and then be transported by the flow into the stormwater system. If the soil contains contaminants, the risk of water pollution is large. To reduce the pollution from contaminated sediments, it is crucial to decrease water erosion. Thus, excavation should be conducted when the weather is dry. Apart from this, it would be preferable to maximise the amount of existing vegetation that could be spared to act as a continuous buffer or cover the entire bare area as soon as possible (ibid.). By utilising vegetation restoration, it could be possible to improve the ecosystem services that decrease soil erosion (Fu et al., 2011).

Dry soil can be less compacted when the heavy machinery is used on top of it, compared to the wet soil (Håkansson, 2005). The best way to reduce soil compaction caused by heavy machinery is therefore to limit the use of heavy machinery or decrease the machinery's weight. Considering that the machinery used for construction does include very specific machines, it may be difficult to change this. It is therefore concluded that the best mitigation measure in this case is to avoid rain events and wait until the soil is dry.

4.7 Bioengineering Approach

New space for future railways will be exploited in this project and new railway ramps are going to be constructed. Without the coverage of vegetation, the soil in the ramps has a high risk of erosion during extreme precipitation rates. To control erosion, an effective bioengineering approach can be applied to the soil in the railway ramps (Fox et al., 2011). The aim is revegetation of the ramps to prevent soil erosion (ibid.). A monoculture of Japanese millet (JM) or JM-dominated seed mixture with buffel grass could be considered as a revegetation method (ibid.). It can be established quickly because of its fast seed germination and seedling establishments and after it starts to die, it takes only one year for the established vegetation to self-generate (ibid.). This approach is able to shorten the revegetation time effectively, which is equivalent to the reduction of risk that the soil erosion occurs due to rainfall and bare surface.

Bioremediation and Phytoremediation

According to The World Health Organization (WHO), ten chemicals are of significant public health concern and seven of them are related to soil pollution (WHO, 2019b; Browning et al., ny). In this project, the focus is on the levels of initial contaminants in the soil and the increasing levels of pollution from traffic. The most effective approach to reduce heavy-metal pollution from traffic is to eliminate the sources of pollution, which means a significant reduction in traffic or the proportion of of heavy-metals found in vehicle emissions (Chen et al., 1999). Considering these two variables are hard to change, the remediation approach is the most fesable to adopt. The following methods of bioremediation and phytoremediation are effective, commonly used within industry and emphasise the biological detoxification and destruction of the organic compounds in contaminants (Zouboulis et al., 2019).

Bioremediation relies on the use of the biological activity of certain microorganisms, which destroy various contaminants (Junior Letti et al., 2018). In comparison, phytoremediation uses plants in order to extract, sequester, and/or detoxify contaminants (Meagher, 2000). In order to avoid the pollution of soil contamination spreading into water sources, remediation should be applied at the source. The main issue is a combination of various methods, which may be needed to treat different types of contaminants (Browning et al., ny). This will definitely increase the costs associated with remediation (ibid.).

4.8 Socio-Economic Aspect

As Flemingsberg is developed and gentrified, the area will become more attractive to individuals and families with higher incomes, therefore, it is likely that housing prices will be affected. This change is not only capable of affecting the incoming population, but also the current inhabitants of the area. The value of privately owned properties and rentals are likely to increase, putting existing, and future tenants in vulnerable economic situations. Socio-economic segregation, due to gentrification, has already been observed in areas within the Stockholm County region which have made similar transitions, such as Solna and Hornstull (Jennische, 2015). According to Sofia Gregorsson from Huddinge Municipality, the goal is to attain a mix of different living possibilities in Flemingsbergsdalen. However, as of now, exact values indicating the types of living, cost, and rent in the area have not been established. In regard to the already high, and continuously increasing rent in newly developed properties, the question is if mixed living development will be sufficient enough to mitigate socio-economic segregation. Even though the development of new areas stimulates and contributes to social and economic growth, housing costs must be adapted to the local population's budget and economic circumstances.

Mitigation could include measures such as guaranteeing a maximum percentage of increase in rent for current inhabitants and planning and building residential areas to accommodate an array of families and individuals with different incomes. To gain the support of current inhabitants of the area, a quota of the jobs created from the project should be reserved for existing, unemployed inhabitants. To stimulate the construction of rentals, an investment subsidy could be granted by the government to the contractor, as well as governmental rental subsidies granted to individuals (Regeringskansliet, 2018).

Health and Safety

Inhaling dust and polluted air particles often result in negative effects on human health, such as an increased vulnerability to, and development of respiratory disease (Zuo et al., 2017; Xing et al., 2018). Dust generating activities should be rescheduled if unfavourable, dry, and windy weather conditions arise (Xing et al., 2018). It is strongly advised that the elderly and young children avoid construction areas with increased dust production and air pollution (Uchiyama, 2013). Furthermore, construction workers should wear dust masks at all times to prevent inhaling harmful construction chemicals (Carbonari et al., 2011).

Effective pollution prevention measures should be implemented and maintained at all times during the project's development phases, as the materials and chemicals used during construction may be harmful to humans, and the receiving environment if mishandled (Snook, 2017). Pollution prevention measures will ensure that pollutant sources, such as liquid and solid wastes, oils, and other chemicals, are safely disposed of to reduce potential pollution risks. As such, any construction vehicles or equipment on site that pose a risk to contributing to pollution should be handled with caution, to ensure that onsite pollution is limited (ibid.).

Both the construction personnel and public passing by, or those residing in close proximity to the development site are at risk of accidental injuries and fatalities during the construction period, in the form of falls into excavated sites, and "struck by" and "caught in" incidents (Carbonari *et al*., 2011; Innovative Safety Products LLC, 2017). In accordance with OHS guidelines, safety measures, including installing site guardrails, using barricade tape, wearing personal protective equipment (PPE), planning for emergencies, and adequate planning of tasks to reduce the risk of accident, must be implemented (Carbonari et al., 2011; Sky Handling Partners, 2012). Additionally, in order to prevent harm or injuries, site conditions should be assessed regularly to ensure that they do not pose any danger, and warning, or precautionary, signs should be displayed and visible at all times. Dangerous and heavy construction equipment and machinery should be operated, and handled by skilled and qualified personnel, as these may cause severe injuries, and even result in the loss of life. Safety awareness of construction workers should also be increased and emphasized through proper occupational, health, and safety (OHS) training, clear communication, and implementation of best practice standards (Carbonari *et al.*, 2011; Sky Handling Partners, 2012).

It is therefore crucial that mitigation measures are implemented and strictly followed to ensure health and safety during construction, as the effects are irreversible. It is important to note that the aforementioned mitigation measures are derived from assumed general construction methods; and as a result, merely emphasize safety measures, even though it is assumed that construction personnel will follow best practice methods to ensure a safe working environment.

Cultural Heritage

Depending on the condition, construction, and material of the artefact in Phase 3-4, the method used in the mitigation process may vary. First and foremost, the plan of action depends on whether the artefact will be excavated or not. If the area holds a burial site or other non-materialistic artefact that does not need excavation, methods of protection should be undertaken. However, it is possible that the artefact may have decomposed or eroded to the degree that an excavation is not possible. Currently, retrieval methods for the item do not exist (Holmquist, 2019; Isaksson, 2019. Personal correspondence). The artefact has not been

identified, and as such, a survey is recommended. The following mitigation assessment assumes that measurements can and may take place.

Apart from the designated area accommodating the artefact, additional space should be reserved in order not to disturb the area (Figure 44). Barriers could be erected in order to protect the area from blasting and disturbance by usage of heavy machinery. The changes in flowpath of the water in the phases must assessed, in order to ensure that new waterways do not cross the area and damage the artefact.

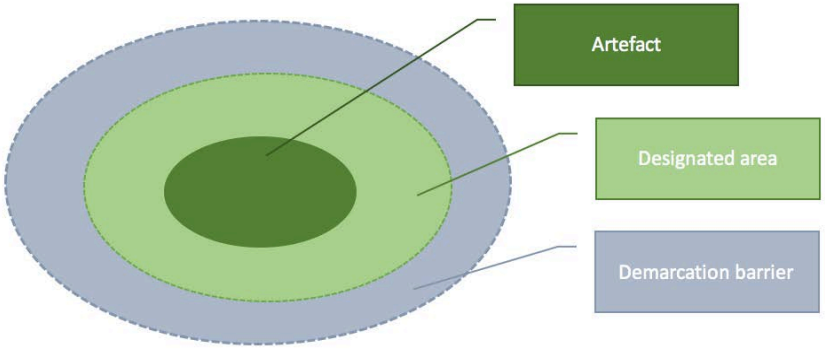


***Figure 44**. Schematic illustration of how an artefact may be protected from physical impact by adding an additional spatial barrier around the designated area.*

The exact process of preservation depends on the artifact's material. There are however a few common rules of thumb when mitigating the deterioration of historical artefacts. Any microorganisms, such as bacteria and fungi, or termites should be delt with because they may damage the artifact's exterior. Humidity and excess moisture should be avoided, as this dissolves salts and may provide exposure to acidic substances which may chemically erode the artifact (Aggarwal, 2014). This may be avoided by adding a protective covering to the artefact.

Buildings

During the construction, large amounts of land will have to be moved and many current buildings will be demolished. However, the buildings that are preserved must be taken into account when construction of the new ones begins. The use of heavy machinery, excavation, and potential blasting causes vibrations which may impact the soil and thereby also impact current buildings. Large vibrations may cause cracks to occur in the buildings walls and may even destabilise the buildings frame. Vibration mitigation materials could be used together with the traditional structure when building the housing (Xu et al., 2019). To reduce the degree of vibration the buildings are exposed to, ground movement should be mitigated as much as possible. It is therefore important that the developers find out where the potential risk area are located. They must also ensure precise and correct measurements, as well as ensuring that the designs of the buildings are stable before construction commences.

5. Cumulative Effects

Cumulative effects are changes to the environment caused by an action, together with other actions from the past and future (Elvin and Fraser, 2012). It is important to consider the cumulative effects in an EIA because one impact alone can be insignificant, but together with other impacts it can be majorly significant and affect the environment in a negative way. Since 2018, the Swedish Environmental Code requires a chapter about cumulative effects to be included in all EIAs conducted within the country.

A good way to identify cumulative effects in an EIA is to use a causal loop diagram (CLD). Further detail on CLDs as an identification method can be found in Section 1.6: *Methodology*. The following sections are based on the CLD, and a detailed description of the cause and effect relationships can be found in *Appendix 4*. There are many cumulative impacts that can affect the future development of Flemingsbergsdalen, and as such, will be addressed in two different sections below, on a regional scale and global scale.

5.1 Regional Scale

The boundary for the regional scale assessment has been set to the city of Flemingsberg. There are several different projects, of various sizes, going on in Flemingsberg at the moment. This assessment will focus on the cumulatives effects of the planned project in conjunction with the two biggest projects nearest to the project area, Tvärförbindelsen Södertörn and Spårväg Syd. This is based on the fact that these projects are likely to affect Flemingsberg, and the project area the most.

Tvärförbindelsen Södertörn

There will be a new road from Kungens Kurva (E4/E20) to Haninge (road 73), for cars, pedestrians, and cyclists. Building of the road is expected to commence between 2021-2023 and will last for eight years. In Figure 45, there is an illustration of where the road will be. As indicated in the figure, the road will run along the upper part of Flemingsbergsdalen. There will also be a tunnel going under the nature reserve. This road will be a primary road for the transport of dangerous goods, unlike Huddingevägen which is a secondary road for this type of transport, which means that more dangerous goods will pass through the area, compared to today (Huddinge kommun, 2019k).

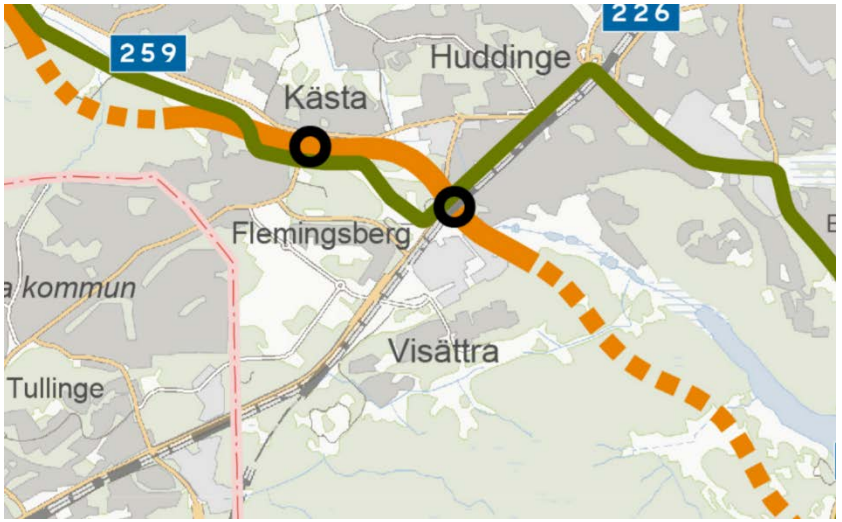


***Figure 45**. An illustration of Tvärförbindelse Södertörn. The orange line indicates the new road for cars, the dotted line is a tunnel, and the green line indicates walking pathways (Huddinge kommun, 2019k).*

Spårväg Syd

There also will be a 17 kilometres tram line running from Flemingsberg to Älvsjö. Building will start in 2020 and will take 10 years to complete. The tram route can be seen in Figure 46. The tram will have one of its terminus stations in Flemingsbergsdalen, on top of the overlay (Huddinge kommun, 2019l).

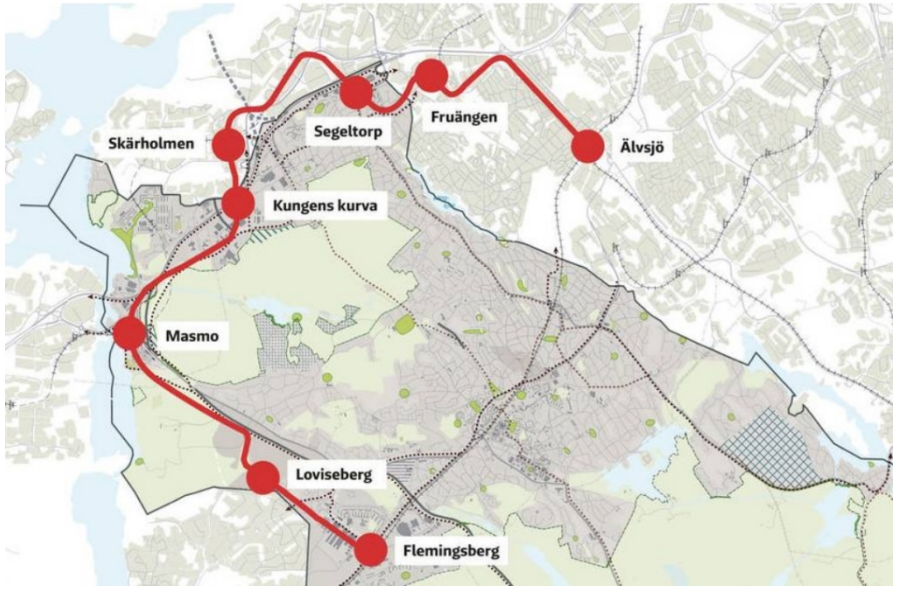


***Figure 46**. An illustration of the future tram line, Spårväg Syd (Huddinge kommun, 2019l).*

The different cumulative effects will be addressed in three sections: ecological health, socio-economic aspects, and human health. These were chosen because they were the three most affected aspects in all of the projects. The discussion below refers to the big CLD in *Appendix 4*. In the following sections, the impacts will be looked at in both the construction and operational phases.

5.1.1 Ecological Health

Ecological health is concerned with biodiversity and includes flora, fauna, and the nature value of an area. During the construction of Tvärförbindelse Södertörn, biodiversity will be affected through noise, air quality, and habitat fragmentation. During the building of Spårväg Syd, similar impacts on biodiversity will occur; however, as the tram is to be constructed on areas that have already been built on, there will be no habitat fragmentation. During the operational phase, most negative impacts on biodiversity will be from noise and air quality, both from the tram and the road. These impacts on biodiversity are illustrated in a concept tree (Figure 47) based on the CLD in *Appendix 4*.

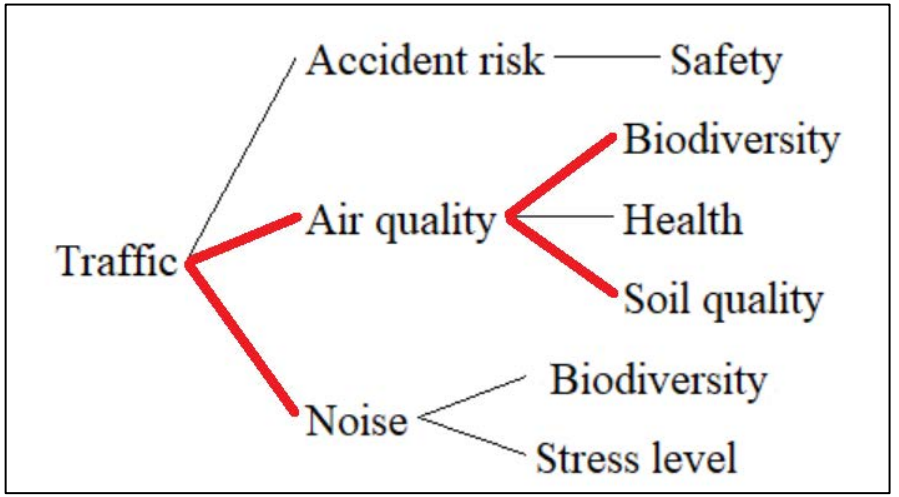


***Figure 47**. A concept tree on how traffic (train, tram, and car) affects different variables directly (ie. air quality) and indirectly (ie. biodiversity). The red lines indicate the variables discussed in the text.*

Not only will air quality and noise affect biodiversity, but indirect impacts from soil quality will also be present, as air quality will affect the soil quality, which in turn, will affect surface water, thus also affecting biodiversity (Figure 48). Soil quality will also affect the quality of the wetland, which is also capable of affecting the water quality in Lake Orlången, thus, affecting biodiversity in and around Lake Orlången.

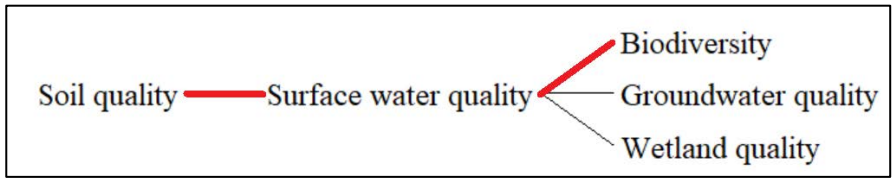


Figure 48*. An illustration of how soil quality will affect different variables directly (ie. surface water quality) and indirectly (ie. biodiversity). The red lines indicate the variables discussed in the text.*

As a result of Tvärförbindelse Södertörn and Spårväg Syd, there will also be more people in the area, which can, in turn, also affect the biodiversity and nature value, through trampling and waste, for example. Both Spårväg Syd and Tvärförbindelse Södertörn have the same impacts as the Flemingsbergsdalen project on biodiversity. Therefore, they are important to consider in this EIA.

5.1.2 Socio-Economic

Equality will be affected by several variables, and is therefore important to take into consideration when looking at the cumulative effects of the planned project, Tvärförbindelse Södertörn, and Spårväg Syd. Employment and housing prices are the only factors that will affect equality directly, however, there are also several variables affecting equality indirectly (see Figure 49). All three projects will further increase connectivity in the area, through both public and private transport, making Flemingsberg and Solgård more accessible than before. Visättra may not reap the benefits of this as much as Solgård and Flemingsberg, as the new tram line will end in Flemingsberg and the new road will pass Solgård (see Figures 45 and Figure 46).

Today, a rental apartment in Flemingsberg, as conveyed by Stockholms bostadsförmedling, costs between 6 000 and 8 000 SEK per month (Bostadsförmedlingen, 2019), and the median income is around 27 500 SEK per month, or 329 800 SEK per year, for people between the ages of 20 and 64 in Huddinge (SCB, 2018b). When buying an apartment in Huddinge, it costs approximately 38 241 SEK/m^2, compared to the city of Stockholm where it costs approximately 54 902 SEK/m^2. However, the prices in the area are likely to rise, due to the increase in connectivity and new development (Figure 49), which is usually associated with higher prices (Davidson et al., 2010).

A change in equality will directly affect safety and indirectly affect stress levels (Figure 50). As stated in *Section 1.3.2 Socio-economic and Public Health,* these factors will have an effect on crime rate, gentrification, and segregation in Flemingsberg.

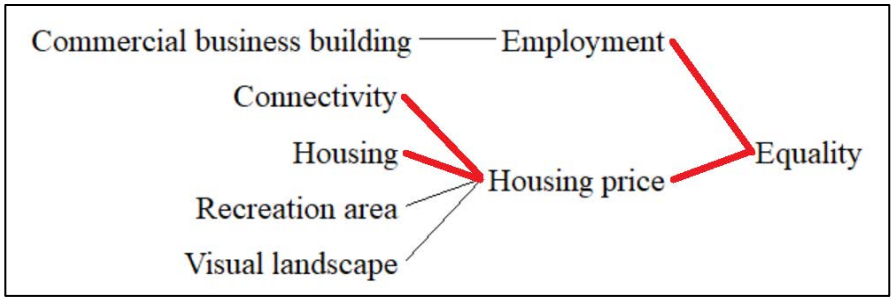


***Figure 49**. An illustration of how equality will be affected by other variables, both directly (ie. housing price) and indirectly (ie. connectivity). The red lines indicate the variables discussed in the text.*



***Figure 50.** An illustration of how equality will affect safety (directly) and stress level (indirectly). The red lines indicate the variables discussed in the text.*

5.1.3 Human Health

According to Adegoke et al. (2013), "Human health, defined as the complete state of physical, social, and mental well-being and not merely the absence of illness, disease, or infirmity, is as vital a resource as water, food, or energy." When considering the lifecycle of the planned project and other ongoing projects, human health will be affected by six different components within the boundaries of Flemingsberg. These six components are environmental noise, recreation, traffic, safety, stress level, and air quality.

Noise Implications on Health

Noise health effects can be defined as the consequences on physical and psychological health, that an individual experience, as a result of being regularly and consistently exposed to elevated environmental sound levels (Münzel et al., 2018). Effects include, but are not limited to, hearing impairment, tinnitus, hypertension, cardiovascular disease, annoyance, and sleep disturbance. There are many potential sources of environmental noise coming from the Flemingsbergsdalen, Tvärförbindelse Södertörn, and Spårväg Syd projects; however, the most significant source is expected to come from road and railway traffic. Besides annoyance, noise will affect human health in many ways. In 2015, the EU compared night-time noise to daytime noise from transport on human health and concluded that night-time noise affects human health more than daytime noise. The study went on to say that night-time noise not only affects the cardiovascular system, but also disturbs an individual's sleep and relaxation. This, in turn, has the potential to lead to stress, due to broken and disrupted sleep. In Flemingsberg, the increased noise from different types of traffic is expected to increase stress levels, and as such, cause adverse effects on human health (Figure 51).

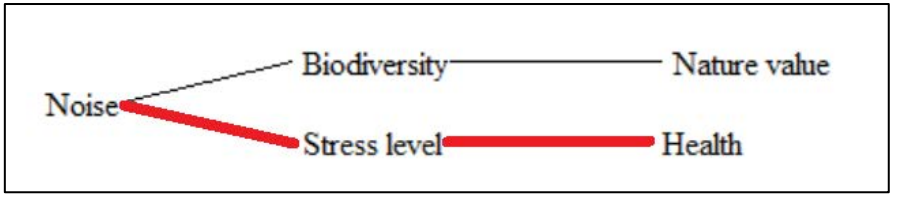


***Figure 51**. An illustration of how noise will affect different variables directly (ie. stress level) and indirectly (ie. health). The red lines indicate the variables discussed in the text.*

Traffic Implications on Air Quality

Potential pollutants emitted in the atmosphere during the development of Flemingsbergsdalen, Tvärförbindelse Södertörn, and Spårväg Syd include particulate matter (PM_{10}), diesel particulate matter (DPM), carbon monoxide, hydrocarbons, nitrogen oxides, and carbon dioxide. These pollutants have the potential to be emitted from heavy machinery used during construction, blasting, the demolition of old buildings, the transport of aggregates and waste, and traffic during the operational stage (USEPA, 2019a). Additionally**,** volatile organic compounds (VOCs) are typically released during construction with the use of oils, glues, thinners, paints, treated woods, and plastics. During the development of these projects, traffic would indirectly affect human health through emissions of pollutants into the atmosphere (Figure 52).

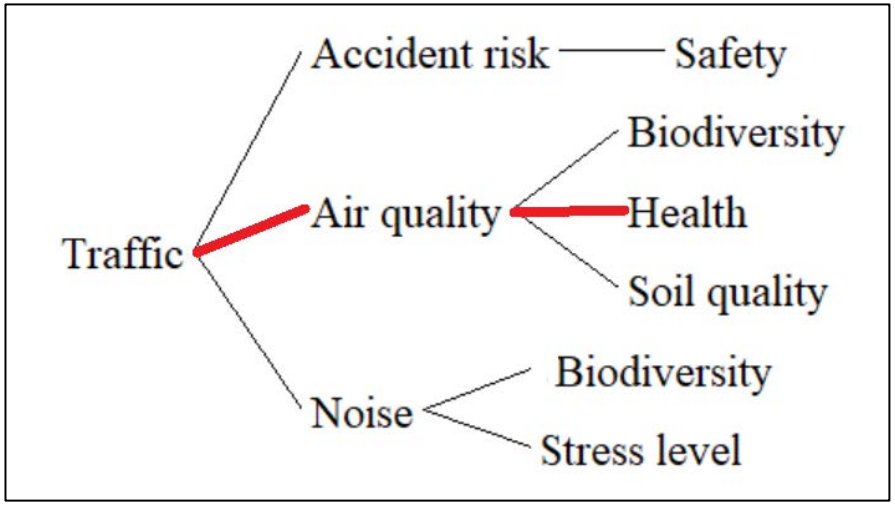


Figure 52*. An illustration of how traffic (train, tram, and car) will affect different variables directly (ie. air quality) and indirectly (ie. health). The red lines indicate the variables discussed in the text.*

Safety

Potential safety risks identified from projects within the Flemingsberg area were deemed to be significant and affect human health indirectly, directly, and cumulatively. Such risks include safety in regard to equality within the city, safety in regard to risk of traffic accidents, and dangerous goods transport within the city. Accidents from traffic can occur during construction, if roads are not properly used by drivers. During the operation, the accidents can be attributed to factors such as speed, lack of orientation, lack of attention and alertness, lack of interpretation and assessment, poor maneuvering, consumption of alcohol, use of drugs and medicine, lack of seat belt use, road and environment conditions, and improper vehicle use (DRTAIB, 2014). In regard to dangerous goods transport, it is expected that there will be no industries in the area requiring dangerous goods, and as such, safety in regard to such transport will decrease.

Because of the expected rise in housing prices in the future (SCB, 2019b), safety within the city is expected to affect health indirectly through gentrification and segregation. Citizens currently residing in the area may be forced to look for alternative housing that fits their economic circumstances. Segregation and gentrification may also lead to crime. Crime in an area often causes individuals to feel unsafe and experience elevated stress levels, thus affecting human health. Less safety in the Flemingsberg area is expected to affect health directly, through injuries, and indirectly, through stress caused by psychological thoughts associated with living in an unsafe environment.

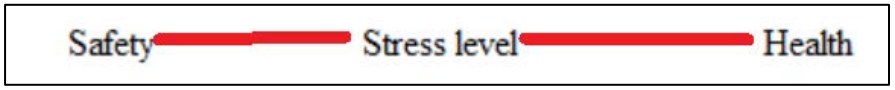


***Figure 53**. An illustration of how safety will affect stress level (directly) and health (indirectly). The red lines indicate the variables discussed in the text.*

Recreation

In Flemingsberg, recreational areas are expected to be both removed and created during construction. Parts of the forested area, where there is currently a walking path in Flemingsberg, are expected to be removed; however, new green parks will be created. The project will incorporate nature by planting trees along all roadways, and designing buildings to accommodate both green rooftops and courtyards. Incorporating green design elements in the plan is predicted to affect human health in a positive way. According to Morris (2003), nature and recreational areas are known to be helpful in recovering from stress and fatigue. Since outdoor recreation is an important part of living a healthy life, the addition of numerous recreational areas in Flemingsberg will allow individuals to partake in activities with friends and family. This will affect health indirectly, by reducing stress levels and promoting active lifestyles within the Flemingsberg area.

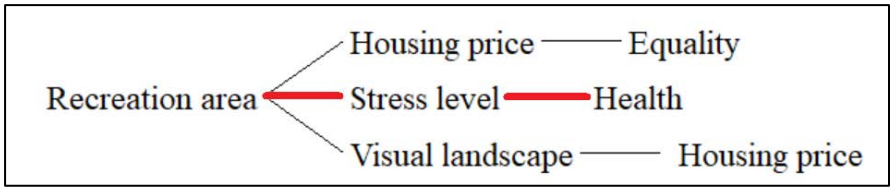


***Figure 54**. An illustration of how recreation will affect different variables directly (ie. stress level) and indirectly (ie. health). The red lines indicate the variables discussed in the text.*

Concluding Remarks on Regional Cumulative Effects

Flemingsbergsdalen, Tvärförbindelse Södertörn, and Spårväg Syd will be constructed at approximately the same time; therefore, the magnitude of impacts on the different indicators will, in some cases, change. For example, it is guaranteed that the magnitude of noise and air pollutants in the area will increase, when all projects are considered. However, the significance of construction on these indicators will not change, as the sensitivity levels will still be low and construction will be short-term. In short, there will still be changes in magnitude in certain indicators, when considering cumulative effects, even if there is no change indicated in the significance matrix.

During the operational phase, traffic will significantly increase, thus, negatively affecting indicators such as air quality and noise level. However, considering the significance has already been assessed as majorly adverse for the project itself, it will be something to address, regardless of the consideration of other projects. Additionally, the connectivity of the area will increase, which will indirectly result in a negative effect on equality; however, the significance of this indicator will not change. In some cases, significance has the potential to change, but more data and research is needed. Therefore, the focus of this regional scale assessment is on magnitude.

In Figure 55, these changes are illustrated and assessed in terms of magnitude. Bubble size is proportional to the amount of change; for example, bigger bubbles indicate a bigger change in the indicator. The colours indicate the type of impact, where orange indicates a large, negative impact, yellow indicates a small, negative impact and green indicates a positive impact.

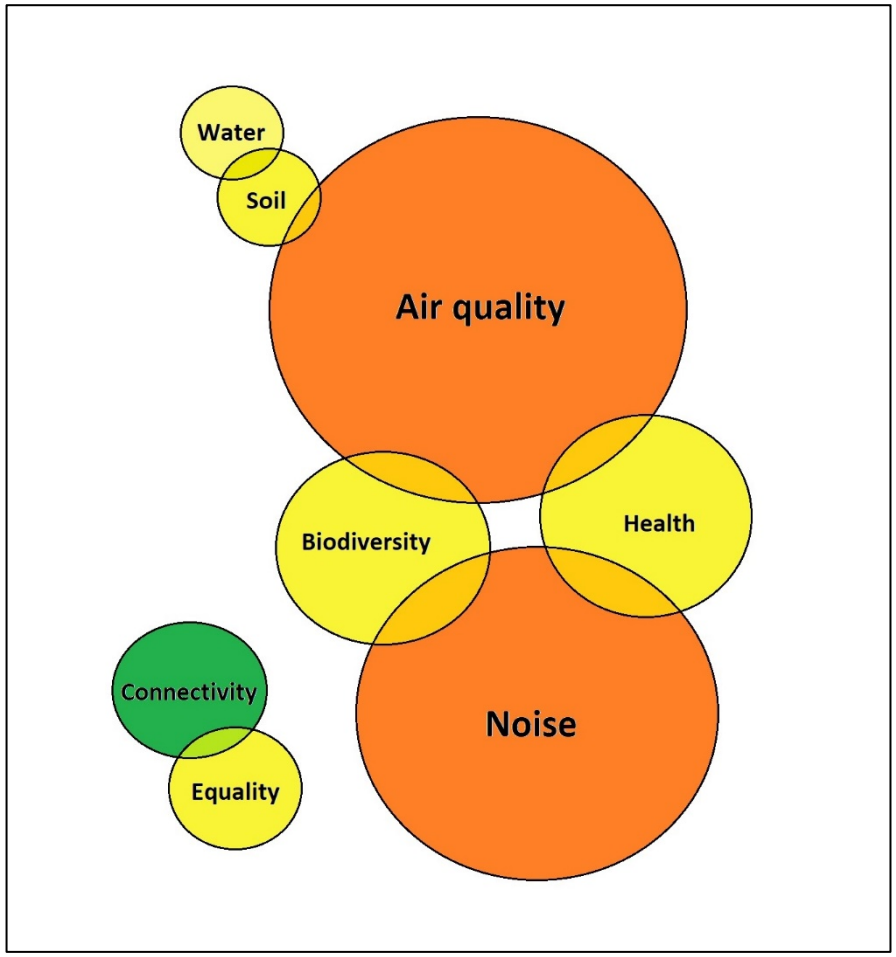


***Figure 55**. The change in magnitude in different indicators is illustrated above. The bubble size is proportional to the amount of change. Green indicates a positive change, orange indicates a large, negative change and yellow indicates a small, negative change. The overlaps mark connections between topics, ie. air quality influences biodiversity, health, and soil.*

The regional scale cumulative impact assessment has shown that it is important to take additional projects and impacts into consideration in the EIA for Flemingsbergsdalen. However, due to time limitations, there is a lack of quantitative data and expert knowledge that requires some more time and research to ensure that all aspects and impacts are covered.

5.2 Global Scale

To put these projects into a wider perspective, the impacts can be viewed on a global scale and through the lens of climate change. Flemingsbergsdalen, Tvärförbindelse Södertörn, and Spårväg Syd will all affect the air quality through the production of greenhouse gases, aerosoles, and other particles. The emissions from Flemingsberg are relatively small, in comparison to the Stockholm County region or all of Sweden; however, the emissions from Flemingsberg will contribute to total emissions, thus, making them important to consider. Sweden's goal for emissions is to reach net-zero by the year 2045 (Naturvårdsverket, 2019f).

Emissions in Flemingsberg will increase during the construction of the project, as well as after construction is complete, as an influx of locals and visitors to the area will cause more transport emissions. The addition of Tvärförbindelse Södertörn to the area will also further increase emissions. It is difficult to calculate future emissions, as they depend on individual car usage. The amount of cars along Huddingevägen is expected to increase in the future, so it is likely that traffic along Tvärförbindelse Södertörn also will increase. The introduction of the tram line, however, will provide locals with a more sustainable mode of transport. The goal of the tram is to have more people taking it, rather than travelling by car. This is beneficial from

an environmental perspective, as it will lower the emissions of greenhouse gases.

The construction and operation of Flemingsbergsdalen is predicted to negatively affect the air quality and contribute to greenhouse gas emissions and aerosols. However, major adverse effects from construction will only last for a short amount of time, and therefore will not have a huge impact globally. According to Table 10 in Section: 3.2 *Summary of Impact Assessment*, the only thing that majorly contributes to greenhouse gas emissions in the operational phase is traffic.

The plan program includes five sustainability goals for the new city, which are as follows: the living area should be safe for and adapted to residents of all ages, there should be an attractive, local economy and labour market, the city should have recreational facilities and be near to nature, the city should be an energy positive city, and all trips should be sustainable (Huddinge kommun, 2019a). To achieve these ambitious goals, the cumulative effects should be taken into consideration. For a living area to be adapted to all ages, it must be a combination of rentals and owned properties (bostadsrätta) that cover all price classes, and adapt to increasing prices over time. Additionally, if there is a desire to maintain natural areas in close proximity, there must be knowledge about planned projects in the surrounding areas and how they will interrupt the nature in conjunction with the planned project. Perhaps, Flemingsbergsdalen will have to implement more recreational and natural areas in order to secure that this goal be achieved, independent of other projects around.

The goals of being an energy positive city and having all trips be sustainable will be majorly beneficial on both the regional, and global scale. These may be the only goals of the Flemingsbergsdalen project that are not dependent on other projects, yet have beneficial impacts on its surroundings.

According to Naturskyddsföreningen in Huddinge, the development of Tvärförbindelse Södertörn is a bad idea, and will lead to continued fossil dependence. Additionally, the goal of sustainable trips, in the plan program, suggests that transport methods other than cars should be prioritized; therefore, the development of Tvärförbindelse Södertörn would hinder the achievement of this goal. Furthermore, Naturskyddsföreningen says that building a large road in close proximity to a residential and recreational area is not good for human health and wellbeing, and also contradicts the UN's global goals. (Naturskyddsföreningen Huddinge, 2019)

6. Climate Change – Effects on Urban Development

As climate change unfolds, cities are required to adapt to the effects of climate change. However, these changes vary between regions and seasons, and are not equally distributed over the globe (Walther et al., 2002); therefore, different cities require different adaptation methods. In Sweden, temperature and precipitation are predicted to increase, especially during the winter and spring. Precipitation patterns are likely to become shorter and more extreme. The mean water availability in the country, as a whole, is predicted to increase in winter and decrease in summer (Eklund et al., 2015). Changes in climatic conditions can affect existing, and future infrastructure. More rain means an increased risk of moisture and mold damage, as well as a higher risk for flooding. An increase in rain will also affect water flow and levels, which in turn, can increase the risk of landslides. Although higher temperatures will decrease the demand for indoor heating, the demand for cooling systems will increase (Klimat- och sårbarhetsutredningen, 2007). All of the predictions above are based on climate scenarios and models. The actual state of the future climate will depend on the amount of greenhouse gases emitted and the world's ability to address climate change, through measures such as decreasing emissions and implementing more climate-friendly actions. As mentioned in *Section 5.2: Global Scale*, Sweden's goal is to have net-zero emissions by the year 2045 (Naturvårdsverket, 2019f). It is important to note however, that even if Sweden does reach this goal, the climate will continue to change if other countries do not act accordingly; thus, it is important to take climate change into consideration when planning a new city.

Future climate conditions in Sweden are capable of affecting Flemingsbergsdalen in various ways (see Table 12). For example, higher temperatures can affect the health of the elderly and children because they are sensitive to, and therefore, more susceptible to the consequences of high temperatures (Thörn et al., 2012). Additionally, the risk of infection spreading can increase when the temperature rises (ibid.). An increase in temperature can not only affect human health, but also infrastructure. For example, heat distortion can occur on the railway, which can affect the operation of public transport (ibid.). Additionally, increased precipitation rates can cause additional moisture to form on buildings, thus resulting in mold, as well as flooding that may affect the infrastructure (ibid.). With changing and increasing water flows, the flora and fauna in the wetland-complex and surrounding area may also be affected (ibid.). Three other possible consequences of climate change include rising sea levels, erosion, and landslides, however, these are considered negligible for Flemingsbergsdalen, as the landscape and location of the area do not make it susceptible to such consequences (Thörn et al., 2012).

Table 12. *Summary of predicted effects of climate change on Flemingsbergsdalen (Thörn et al., 2012).*

Consequence of Climate Change	**Effect on Flemingsbergsdalen**
High temperatures	Health risk for elderly and children Spread of infection Heat distortion on the railway
Increased precipitation	Moisture and mold damage on buildings

	Damage on infrastructure from flooding
Increased sea level and changed water flows	Flooding of wetland Negligible consequence of increased sea level in Flemingsbergsdalen
Erosion and landslides	Negligible for Flemingsbergsdalen

On August 1, 2018, a change in legislation was made regarding the Planning and Building Law (PBL), with the aim of improving municipalities' abilities to cope with climate change. A municipality now must clarify the risks of climate change in their comprehensive plan (PBL 2010:900 3 kap 5§) (Boverket, 2018). Although the inclusion of climate adaptation measures are not legally required until the detailed plan is made, a municipality has the responsibility to ensure that the precautionary principle is followed, and that all new construction carried out has climate adaptation in mind (Swedish Government, 2017).

The Huddinge Municipality has developed an action plan for climate adaptation. In this plan, the municipality has created a list of different, prioritized actions that need to be implemented. One of the highest prioritized actions is to do stormwater management for new construction areas in an early stage (Huddinge kommun, 2017). Despite the municipality's plan, no specific assessment or dedicated chapter of urban climate adaptation is mentioned in the plan program for Flemingsbergsdalen. However, stormwater management has been thoroughly investigated, along with resilient and climate adapted species, and is somewhat incorporated in the plan program.

As shown in Table 12, buildings and humans in Flemingsbergsdalen will be affected by climate change, therefore, it is important to consider in urban planning. Ideally, when the plan program is approved in April and the work with the detailed plan starts, the Huddinge Municipality will suggest climate adaptation measures for each phase. As various responsibilities lie between the municipality and the developer, the question of who is responsible for climate adaptation will be complex and complicated to address (Swedish Government, 2017). Therefore, communication and collaboration is encouraged in developing the climate adaptation actions of Flemingsbergsdalen, in order to have the best climate adapted and sustainable city.

Part 3: Monitoring



7. Monitoring

The objective of an EIA is to carry out an assessment that is as accurate as possible. However, it is not always possible to assess all the environmental consequences associated with the implementation of a project. In certain cases, effects may only emerge years later. Therefore, it is recommended to set up a monitoring system that is complementary of and controls mitigation measures, and monitors the general status of the environment, if possible and applicable. Additionally, monitoring systems can be useful for gathering information that can improve project management and aid in decision-making, if necessary, pertaining to the application of mitigation measures (Glasson et al., 2012). Different variables can be measured both before decision making, and during the lifetime of the project, to check the functionality of structures and installations, and to study the magnitude of different impacts (ibid.). Despite its importance, monitoring is currently not mandatory in many EIA procedures and guidelines in the EU, including those in Sweden (ibid.). Thus, the following does not claim to be a comprehensive monitoring plan, but rather serves as a guideline. Additionally, experts from relevant disciplines should be consulted in order to plan and implement the monitoring measures, as well as to record and assess the results.

7.1 Natural Environment

Biodiversity

Monitoring of biodiversity is done to clarify the impact the project has on species richness, animal behaviour, and the status of the vegetation. Species composition can be monitored by taking an inventory of the species observed in the area. The creation of a species richness index, by monitoring the number of a certain type of species present in the area, could also be useful (Landcare Research New Zealand Ltd., 2005). A species inventory is highly suggested to be done in and around the nature reserve, Flemingsbergsskogen, to see if biodiversity is affected. It is important to note, however, that a border effect, or habitat fragmentation, is likely to occur where the studied area cuts off, which may cause harm to high-value nature environments.

An inventory of the species richness in the wetland-complex could also be of value, to see if an indicator, such as noise or light pollution, affects the composition or amount of species in the wetland.

According to the plan program, many of the buildings in the area will have green roofs. Regardless of the type of green roof, maintenance is required. The drainage system of each green roof should be inspected twice a year. Additionally, to promote high biodiversity on green roofs, maintenance of vegetation is also necessary. Thus, monitoring is strongly recommended to ensure that all green roofs are being properly maintained (Petersson et al., 2017).

Air Quality

Air quality monitoring is done to determine whether guideline standards are exceeded, as well as to estimate population exposure levels to air pollutants and resulting effects on health. According to a study done by the European Commission (EC) (European Union, 2017), 3 out of 4 people suffer from the effects of air pollution within urban areas in Europe. Thus, monitoring is important in Flemingsbergsdalen, as it will be an urban city. Although monitoring is not mandatory in the EIA process, it should not be overlooked. Furthermore, it is wise to include monitoring to manage the

area after project implementation, and to comply with guideline regulations highlighted by the Swedish Environmental Protection Agency (SEPA, 2019).

It is important to measure levels of exposure to air pollutants in the population, especially for children at a young age, who are more susceptible to the negative effects of air pollution. Measurements should also consider elderly people and people with chronic illnesses. In doing so, predictions can be made and information gathered in order to determine the relationship between exposure levels and their corresponding health effects (WHO, 1999).

The air quality in Flemingsbergsdalen can be monitored in a similar manner to Hornsgatan in Stockholm (Stockholm Stad, 2019). Pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), and ozone (O_3) can be monitored using the same methods that are currently used in parts of Stockholm.

Air quality, in and around forested areas of the project, can be monitored by taking inventories of the composition of lichen species within the area. Certain lichens are more sensitive to changes in air quality, and others are more resistant (Malmqvist, 2003). Therefore, lichens can work as an indicator species.

Stormwater

Monitoring the quality of stormwater is important for sustainable environmental management. Monitoring the water quality in the sedimentation pond discharging into the wetland, along the wetland-complex, and in the recipient, Lake Orlången, is something to consider. This is important to monitor along the drainage pathway to determine where the responsibility lies. For example, changes in the recipient may arise due to activities in Flemingsbergsdalen or from other sources, such as Trafikförbindelsen Södertörn. A warning system that tracks harmful trends could be useful, so that it is possible to apply more remediative measures before the EQS are negatively affected by the development of Flemingsbergsdalen.

Regardless of how the stormwater pond is constructed, it requires regular maintenance for it to remediate the water effectively. A natural remediation system, like a pond, can lose effectiveness relatively quickly (Andersson et al., 2013), therefore, monitoring the pond status is necessary.

Groundwater

Monitoring of the groundwater levels in the area is needed before construction of the project commences. It is important to have knowledge on natural groundwater fluctuations in the area, and know where groundwater pumping is necessary. If the pumping of groundwater is required to proceed with the building process, the developer must apply for a permit for water operations with the environmental court. Additionally, the post-monitoring of groundwater levels can be useful to ensure that such levels return to stable states after water operation. Groundwater monitoring can also provide an idea of contamination levels in the soil.

Noise

After completion of the Flemingsbergsdalen project, the major noise sources are predicted to be roads, railways, and trams (Tyréns, 2019b). It is important to measure and assess the nature and characteristics of noise, as potential adverse health effects can be associated with noise.

Monitoring should be done to determine if guideline levels have been exceeded, an environmental nuisance has been caused, and mitigative measures are necessary. Public opinion is necessary to proceed with the investigation and monitoring of noise, as the public are affected by such noise. It is recommended to gather information about, but not limited to, the type of noise, what noise is generally disturbing the public, the duration of noise, and the frequency of noise. To further assess sound levels, it is recommended that measurements be taken, with the consideration of weather conditions, at the sources of noise, mentioned above, and in recipient areas that are most sensitive to sound.

7.2 Cultural Environment

The cultural environment comprises the visual and aesthetic value of the landscape, as well as the cultural heritage. In particular, the visual landscape and its aesthetic value are highly subjective, based on individual perception, and therefore, difficult to monitor. Additionally, the question of whether or not it is necessary to monitor the changing perceptions of citizens, regarding the visual landscape over the lifespan of the project, should be raised. Firstly, individual perceptions can change very quickly and frequently, as well as vary to a great extent between social groups. And secondly, possible improvement measures may exceed the available time and financial resources. In the case of the visual landscape, it is particularly advisable to conduct surveys before the project starts to minimise risk of public complaints.

During the operational phase, a substantial increase in people living and visiting the area, compared to the present time, may lead to possible negative effects on cultural heritage, through an increase in waste or vandalism. However, vandalism does not frequently occur at these sites, and is unlikely to increase with project operation; therefore, monitoring measures pertaining to cultural heritage are desirable, but not necessary.

7.3 Socio-Economic Environment

During the construction phase, health and safety mitigation and monitoring measures are essential to minimise the risk of injury and fatality, for both construction personnel and the general public (Carbonari et al., 2011). For health and safety, the focus is more on compliance monitoring to ensure that OHS guidelines are implemented and effective. The construction team must have a health, safety, and environment (HSE) officer or designated personnel, who has had OHS training, to monitor and ensure that the work environment is safe at all times. This should be done periodically, and is recommended to be done each day before the commencement of tasks. Together, with toolbox talks, workers can be reminded of safety measures and other concerns associated with their tasks that day. Additionally, the records of both safety and environmental incidents, as well as preventive or corrective measures implemented should, and must be kept.

Monitoring for other social aspects, such as social cohesion, should be done through the use of quantitative methods, such as questionnaires or surveys for residents, during the operational phase. This form of monitoring will help in determining whether or not the development objectives, such as improving employment and promoting social integration through recreational, cultural, and leisure activities, have been met. In terms of employment opportunities, both local and non-local employment seekers must be given fair and equal opportunities.

8. Closing remarks

This report is a result of the EIA process for the Flemingsbergsdalen project. At first, the proposed location of the project seems to be optimal, with low nature values, already developed infrastructure and a region ideal for expansion and renewal. However, from an ecological point of view, when taking into account the surroundings and the impacts of additional exploitation due to, for instance, the construction of a new highway (Tvärförbindelsen), the picture alters slightly. The project site is located in close proximity to two sensitive and susceptible nature areas (Flemingsbergs nature reserve and Lake Orlången). The impact of actions on indicators located within the project area that have been deemed of low significance, are given another assessment ranking once the recipient changes. The development of the Fleminsgbergsdalen project would not only put more pressure on the nature reserve, but also on stormwater management and, together with the proposed highway, the need for additional regulation of noise and air pollution.

Additionally, the plan program suggests that a development like Flemingsbergsdalen would minimize the social, and economic segregation of the area by creating new jobs and making the area more culturally and socially attractive. This EIS also identifies the proposed developments as having a positive impact on the area, however, problems with gentrification (resulting in more segregation) in previous projects within similar areas, should be observed and appropriate action should be taken in order to avoid this.

Although the design of the Plus Alternative favors ecological and environmental aspects, certain trade offs arise; the implementation of the Plus Alternative might result in increased construction and developmental costs, and a true cost-benefit analysis has not been thoroughly investigated in this report.

Despite the possible negative effects of the proposed development, the plan program presents good insight of the development and several suggestions for facilitation and prevention of the challenges mentioned above. Even though the program includes awareness of future challenges regarding stormwater and higher temperatures due to climate change, there is a concern that the suggested measures are not adequate.

In order to accomplish the vision and goals of having a cultural, social and flourishing city centre, providing the Flemingsbergs inhabitants a basis for work, education and recreation, both the planned project and the Plus Alternative suggested within this report can accomplish these goals. However, there is a large emphasis on keeping segregation, stormwater management and future climate change in constant consideration when planning the future development of Flemingsbergsdalen.

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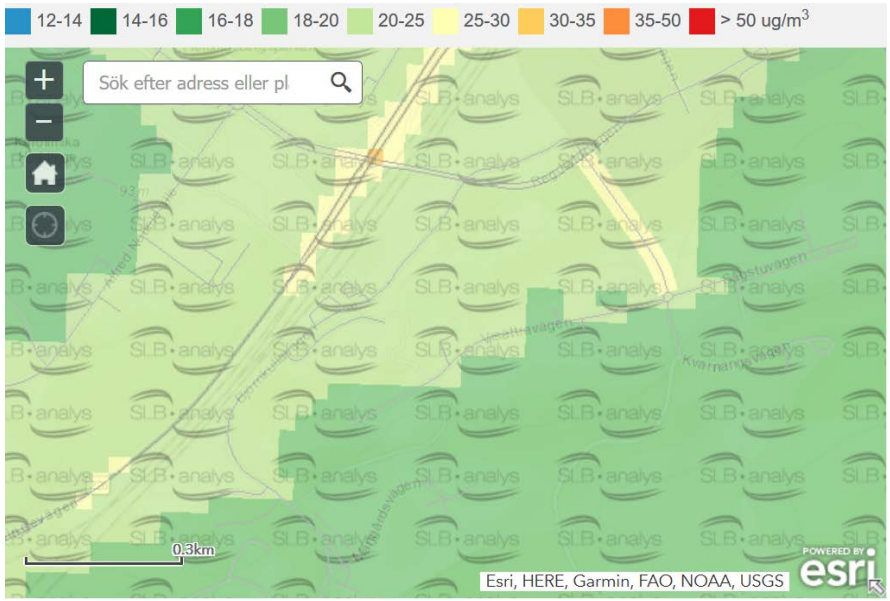
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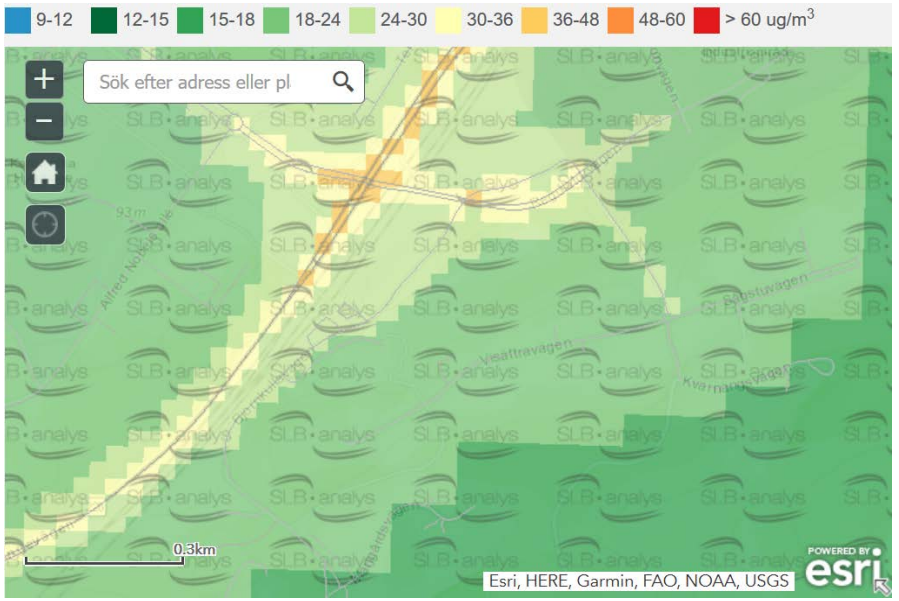
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Background pictures for front page, part1, part2 and part3:
Huddinge kommun. 2019a. Planprogram för Flemingsbergsdalen. KS-2018/1281.313 HUDDINGE KOMMUN/2019-10-21. https://www.huddinge.se/contentassets/fe4b3ec0dd794ec6a2d4c13b7d5a5603/planprogram-for-flemingsbergsdalen.pdf (Accessed 2019-12-10).

Appendix 1



***A**. Measured PM_{10} levels within Phase 1 project boundaries, located on the right of Huddingevägen, along Bjornkullavägen and just after Regulatorvägen (SLB analys (2015) on behalf of the Eastern Swedish Air Transport Association).*



***B**. Measured NO_2 levels within Phase 1 project boundaries, located on the right of Huddingevägen, along Bjornkullavägen and just after Regulatorvägen (Source: SLB analys (2015) on behalf of the Eastern Swedish Air Transport Association).*

Appendix 2

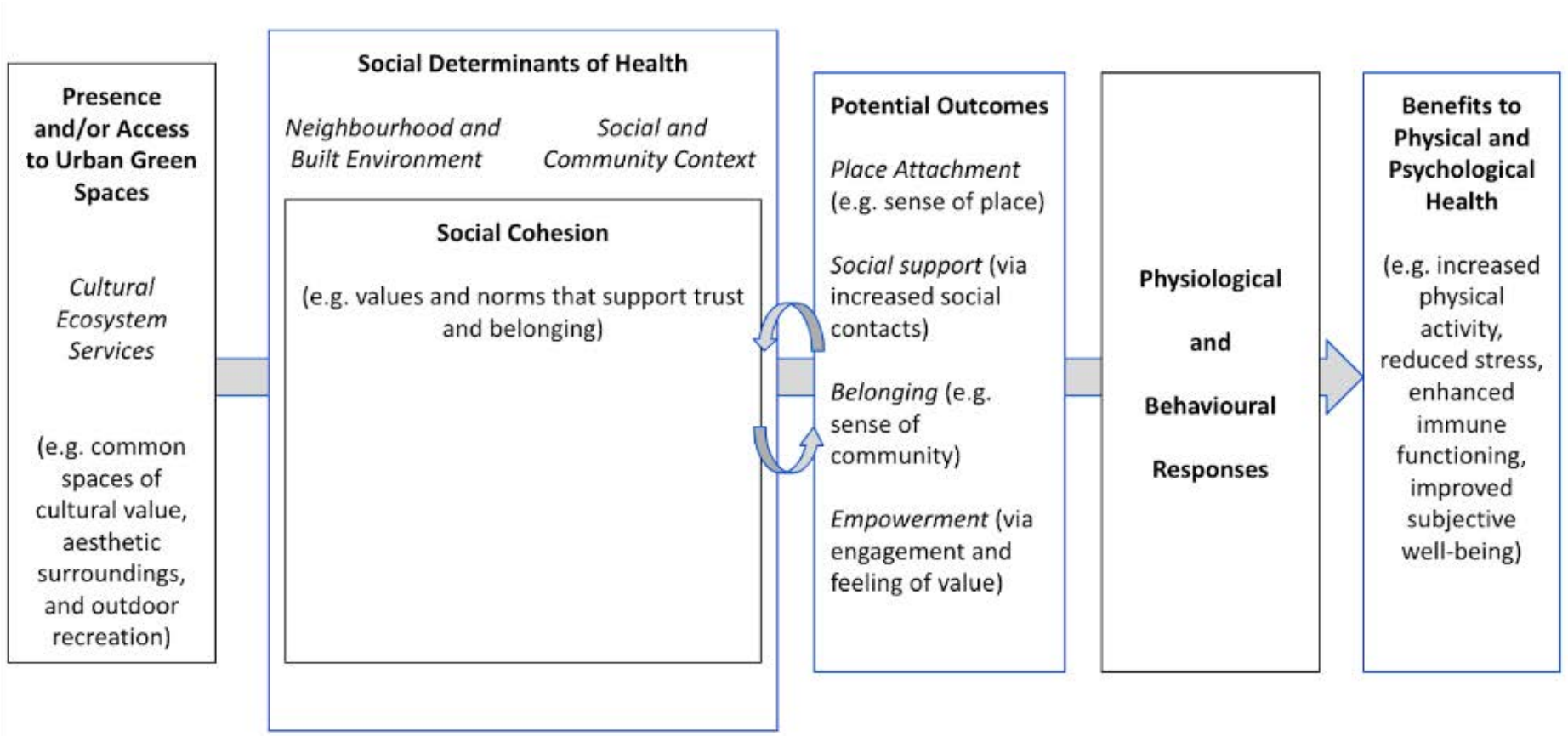


Figure A. *The relationship between cultural ecosystem services, the formation of urban green spaces and social cohesion with social and health outcomes (Source: Jennings and Bamkole, 2019).*

Appendix 3

***Table 1**. Guidelines for noise from Construction Sites (Construction Noise Levels) (Information and table Adapted and altered from Naturvårdsverket, 2019d).*

Area	Mon-Fri		Sat, Sun, Holiday		All Days	
	Day 07:00-19:00 Equivalent sound level	Evening 19:00-22:00 Equivalent sound level	Day 07:00-19:00 Equivalent sound level	Evening 19:00-22:00 Equivalent sound level	Night 22:00-07:00 Equivalent sound level	Night 22:00-07:00 Maximum sound level
Housing for permanent living and holiday homes						
Outdoors (next to facade)	60dBA	50dBA	50dBA	45dBA	45dBA	70dBA
Indoors (a room)	45dBA	35dBA	35dBA	30dBA	30dBA	45dBA
Classrooms						
Outdoors (next to facade)	60dBA					
Indoors	40dBA					

Work Rooms for quiet activities*						
Outdoors (next to facade)	70dBA					
Indoors	45dBA					

* This means premises for non-noisy operations with demands for constant concentration or need to be able to carry on calls without difficulty.

Table 2. *Guidelines for noise from roads and railways in new buildings, recreational areas (Operational Noise Levels) Naturvårdsverket, 2017a).*

Level of Sound	Location
Roads, railways, new buildings	
30 dBA	Maximum indoor level at night
45 dBA	Maximum level at night
55 dBA	Equivalent outdoor level (at facade)
70 dBA	Maximum level at patio in connection with housing
60 dBA	Equivalent level at patio in connection with housing
Railway or other track installation,	
55 dBA	Equivalent level outdoors
Recreational areas in urban areas	
55 dBA	Equivalent level

Appendix 4

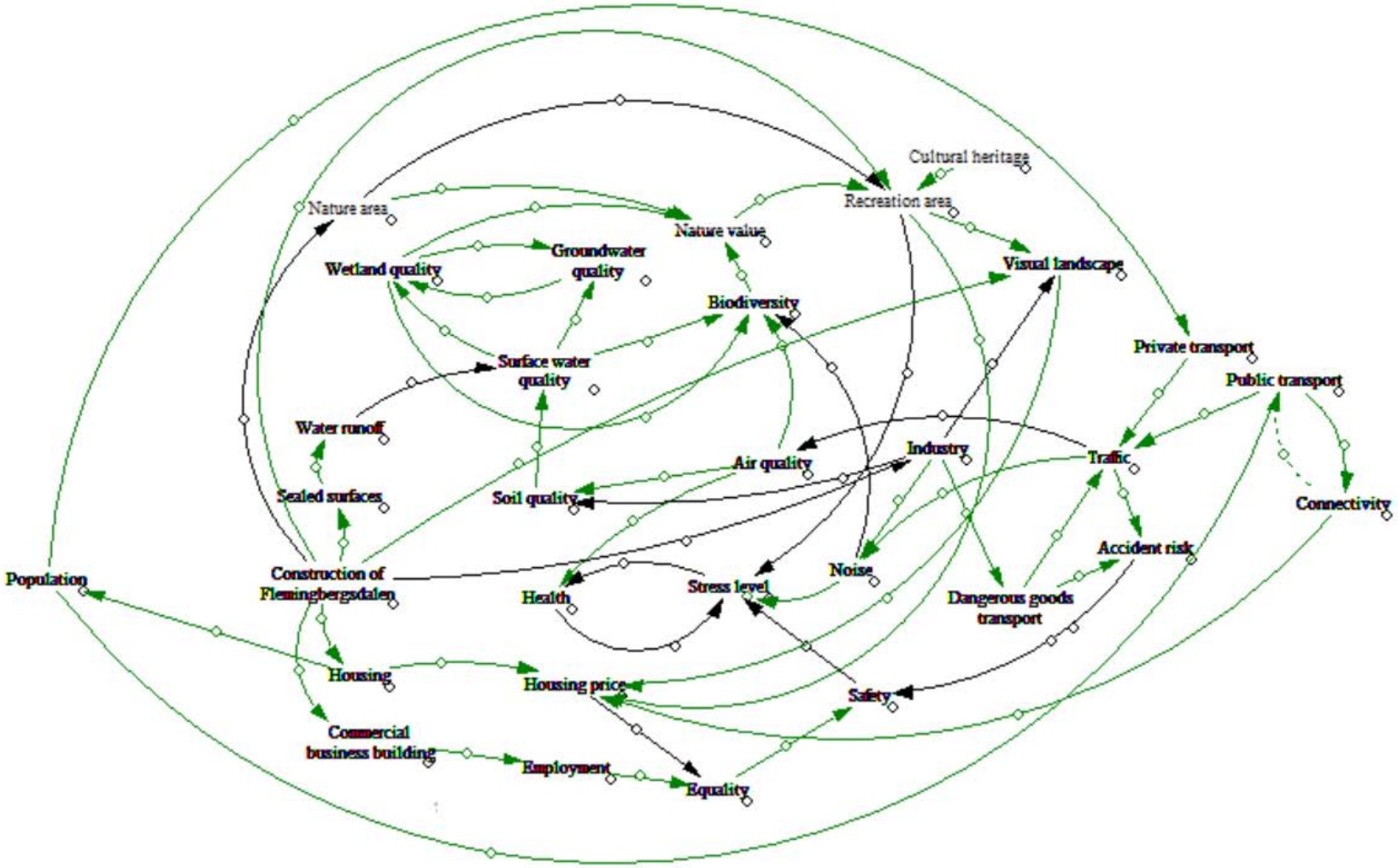


Figure A. *CLD over Flemingsbergsdalen. Green arrow are a positive change and black arrow are a negative change.*

Description of CLD in Figure A

Development Starts with Construction of Flemingsberg

Nature Area & Recreation Area: Increase in the construction of Flemingsberg would cause a decrease in the existing nature area by clearing of the forest. A decrease in the nature area would cause a decrease in recreation area (forested area) and nature value. A decrease in recreation area would cause an increase in stress level. An increase in stress level would cause a decrease in health. Less health causes more stress level.

Increase in construction of Flemingsberg would also cause an increase in newly constructed recreation area. Increase in recreation would cause an increase in housing prices. Increase in housing prices would decrease equality. Less equality would cause a decrease in safety. Less safety in the city would increase stress level. More stress level causes health to decrease. Decrease in health causes an increase in stress level.

An increase in construction of Flemingsberg would increase visual landscape. An increase in recreation would also cause an increase in the visual landscape. An increase in visual landscape would cause an increase in housing prices. An increase in housing prices would cause a decrease in equality. Less equality would cause a decrease in safety. Less safety in the city would increase stress level. More stress level causes health to decrease. Decrease in health causes an increase in stress level. An increase of cultural heritage would cause an increase in recreation area.

Sealed Surfaces: An increase in construction of Flemingsberg would lead to an increase sealed surfaces. An increase in sealed surfaces would cause an increase in water runoff. An increase of water runoff would decrease surface water quality. A decrease in the surface water quality would cause a decrease in wetland quality and groundwater quality. A decrease in the wetland quality would cause the groundwater quality to decrease. As the groundwater quality decreases the wetland quality would decrease also. As the wetland quality decrease biodiversity decreases. Less biodiversity would cause a decrease in the nature value. As wetland quality decreases nature value decreases.

Housing: An increase in construction of Flemingsberg would cause an increase in housing. An increase in housing would lead to an increase in population and house prices. An increase in population would cause an increase in private and public transport. More private and public transport would lead to an increase in traffic.

An increase in traffic would cause a decrease in air quality. A decrease in air quality would cause a decrease in soil quality. Decrease in soil quality can lead to a decrease in surface water quality. A decrease in the surface water quality would cause a decrease in wetland quality and groundwater quality. A decrease in the wetland quality would cause the groundwater quality to decrease. As the groundwater quality decreases the wetland quality would decrease also. As the wetland quality decrease biodiversity decrease. Less biodiversity would cause a decrease in the nature value. As wetland quality decrease nature value decreases.

A decrease in air quality would lead to a decrease in health. A decrease in health would cause an increase in stress levels, which would further decrease health. A decrease in air quality would also cause a decrease in biodiversity. A decrease in biodiversity would cause a decrease in nature value. Decrease in nature value would lead to a decrease in recreation area. A decrease in recreation area would cause an increase in

stress level. An increase in stress level would cause a decrease in health. Less health causes more stress level.

An increase in traffic would also increase noise. An Increase in noise would increase stress level. An increase in stress level would cause a decrease in health. Less health cause more stress level.
An increase in traffic would also lead to an increase in accident risks. More accident risks cause a decrease in safety. A decrease in safety would cause an increase in stress level. An increase in stress level would cause a decrease in health. Less health causes more stress level.

An increase in housing would cause house prices to increase. As house prices increases, equality decreases. Less equality would cause a decrease in safety. A decrease in safety would lead to an increase in stress level. More stress causes health to decrease and less health cause an increase in stress level.

An increase of public transport would also lead to an increase in connectivity. An increase in connectivity would cause an increase in house prices. As house prices increases, equality decreases. Less equality would cause a decrease in safety. A decrease in safety would lead to an increase in stress level. More stress causes health to decrease and less health cause an increase in stress level.

Commercial Buildings: An increase in construction in Flemingsberg would cause an increase in commercial buildings. An increase in commercial buildings would cause an increase in employment. An increase in employment would cause an increase in equality. An increase in equality would cause an increase in safety. Increase in safety would decrease stress level. Less stress level would cause an increase in health. More health would cause less stress level.

Industry: An increase in construction in Flemingsberg would cause a decrease in industries. Less industries would cause a decrease in dangerous goods being transported. A decrease of dangerous goods being transported would cause a decrease in traffic. A decrease in traffic would decrease accident risks. A decrease in accidents risks would cause safety to increase. More safety would decrease stress levels. As stress levels decreases health increases. As health increases stress levels decreases.

A decrease in industry causes a decrease in noise. Decrease in noise would decrease stress level. As stress levels decreases health increases. As health increases stress levels decreases.

A decrease in industry would also increase soil quality. Increase in soil quality can lead to an increase in surface water quality. An increase in the surface water quality would cause an increase in wetland quality and groundwater quality. An increase in wetland quality would cause the groundwater quality to increase. As the groundwater quality increases the wetland quality would increase also. As the wetland quality increase biodiversity increases. More biodiversity would cause an increase in the nature value. As wetland quality increases nature value increases.

As industry decreases the visual landscape increases. An increase in visual landscape would cause an increase in housing prices. An increase in housing prices would cause a decrease in equality. Less equality would cause a decrease in safety. Less safety in the city would increase stress level. More stress level causes health to decrease. Decrease in health causes an increase in stress level.

Definitions to CLD in Figure A

Variable	Definition
Nature value	Quality of nature, amount of species
Wetland quality	Quality of wetland
Groundwater quality	Quality of groundwater
Surface water quality	Quality of surface water
Biodiversity	Flora, Fauna
Nature area	Total area with nature
Soil quality	Quality of soil
Air quality	Quality of air
Health	Health for a person
Housing	Amount of houses
Construction	Exploit new areas
Stress Level	The amount of stress for a person
Noise	Amount of noise
Sealed surfaces	Amount of sealed surfaces
Water runoff	The possibility for runoff
Recreation area	Total area for recreation
Visual landscape	Aesthetic value of the landscape
House prices	Price of an apartment
Safety	Safety of workers and for residents
Accident risk	The risk of accidents
Traffic	Total traffic
Private transport	Total transports in private car
Public transport	Total transports with public transport
Connectivity	Connectivity in the city
Cultural heritage	Cultural buildings
Dangerous goods transport	Total transports with dangerous goods
Industry	Amount of industries
Equality	Segregation, gentrification, accessibility for wheelchairs and

	disabled persons, ethical segregation etc.
Employment	Market accessibility for companies
Commercial business buildings	Amount of business buildings