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MANAGEMENT OF STORMWATER AND GROUNDWATER GENERATED DURING CONSTRUCTION PHASE OF LARGE-SCALED INDUSTRIAL FACILITY – CASE HANHIKIVI-1, NUCLEAR POWER PLANT

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ABSTRACT

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Stormwater runoff formation in industrial areas during construction is a significant factor of hydrosphere pollution. To prevent and mitigate the contamination of the environment, it is important to organize the stormwater management system on construction sites.

The development of a stormwater and groundwater management system during the construction phase is considered by the example of Hanhikivi-1 nuclear power plant. While developing the stormwater management system, one of the challenges was reviewing the existing stormwater system units as settlings pounds in terms of the ability to collect and convey wastewater in case of rain of varying intensities. This thesis considers the issues of organization stormwater management, including dewatering of the pit for the main building and structures Hanhikivi-1 NNP in compliance with environmental regulation and requirements. The significant part of this thesis was to check the existing ponds for simulation of flooding during rain with different intensity and repeatability and to adjust the capacity of general units of the designed stormwater system to prevent the flooding of the main pit above -17,0 m elevation.

As a tool for simulation of rain with different intensity occurs in considered area of Hanhikivi-1 NPP was used the Implicit Solver (Sewer GEMS Dynamic Wave) of Bentley software. The system was computed for different design cases: 5, 10, 50, 100 years return period rain. As a result of computing the stormwater, a management system was developed and the general parameters of the main units were defined as follows: the capacity of pumps, the dimensions of the designed pond, the routing of the roadside ditches, and the cross-sections of the ditches.

CONTENTS

1 INTRODUCTION

Because of hard-to-predict nature of rains and high rate of instantaneous runoff, the crucial issue is proper determination of the stormwater amount generated on construction site. The subject of this thesis was chosen since the project for the management of ground and stormwater generated at the construction site of Hanhikivi-1 NPP is under development, and I was interested to participate in the discussion of this issue. Hanhikivi-1 NPP project is being transferred to the active stage in 2021-2022, which means that preparations for the construction of the main buildings and structures are starting. One of the initial works is the excavation of the pit to the design heights for the main buildings and structures, and one of the most important issues is to ensure proper management of ground and stormwater on the construction site, which contributes to the safety and efficiency of the work. The main concern in this stage was the capacity of existing ponds from the ensuring the dewatering of the pit and conveying the surface stormwater during rain point view. At the beginning of 2021, an additional geological study was carried out to assess the amount of groundwater seeping into the quarry, which contributes to a more accurate assessment of the total inflow of groundwater and stormwater into the pit.

At the current moment the comprehensive management system of ground and stormwater is not existent, thus one of the tasks of this thesis is to design this system. The computing scheme of collecting and conveying wastewater generated on the construction site was developed. The scheme includes existing ponds for simulation flooding during rain with different intensity and repeatability. During this simulation the capacity of main units, as well as the capacity of pumps, the dimension of the design pond, the routing of roadside ditches and ditch cross section was chosen. The existing ponds were checked for different design cases: 5, 10, 50, 100 years return period rain.

2 BACKGROUND

Stormwater runoff formation in urban and industrial areas is a significant factor of hydrosphere pollution. Undeveloped or grassy areas, such as parks and lawns, soak up most of the rain that falls there. Therefore, there is much more polluted stormwater runoff in areas with large amounts of impervious or paved surfaces. The stormwater picks up all the pollutants along its pathway. As polluted stormwater runoff is caused by so many of our everyday activities and processes which are run in industrial plants, stormwater runoff should be collected and purified in the cases regulated by legislation. In order to decrease harmful influence on the environment and prevent the pollution of water courses, the municipal environmental protection authority has regulations on the quality of stormwater if it is conveyed directly into watercourses.

The quality of stormwater depends on the characteristics of the catchment area. Different surfaces can be qualified by several characteristics such as material composition of the surface, type and degree of urbanisation, weathering processes, surface slope and spatial location. The most important characteristic determining the quality of stormwater runoff is the territory function where runoff is formed. The surfaces generating urban runoff can be divided into three main types, that are: recreation areas (e.g., urban green spaces, forest parks, lawns), urban areas (courtyard buildings area, city roads) and industrial areas (territory of possible formation of specific pollution – plants with various function).

In addition to catchment properties, runoff event characteristics affect the stormwater quality, such as intensity and duration. Because of the hard-to-predict nature of rains the significant issue is the proper determination of the amount of water conveyed to purification. Rains vary in intensity during the warm months, they may be low-intensive and upper-intensive and have different duration.

Open data of instantaneous weather observation was obtained from Finnish Meteorology Institute. The data of precipitation amount was analysed for weather observation station "Oulu Oulunsalo Pellonpää", the observation period is ten years from 1 June 2010 till 1 June 2020. The results can be seen in Figure 1: the most prevalent for Oulu area are the low-intensity and recurring rains with precipitation level 1,0- 5,0 mm. (FMI. Open data of instantaneous weather observation, 2010-2020)

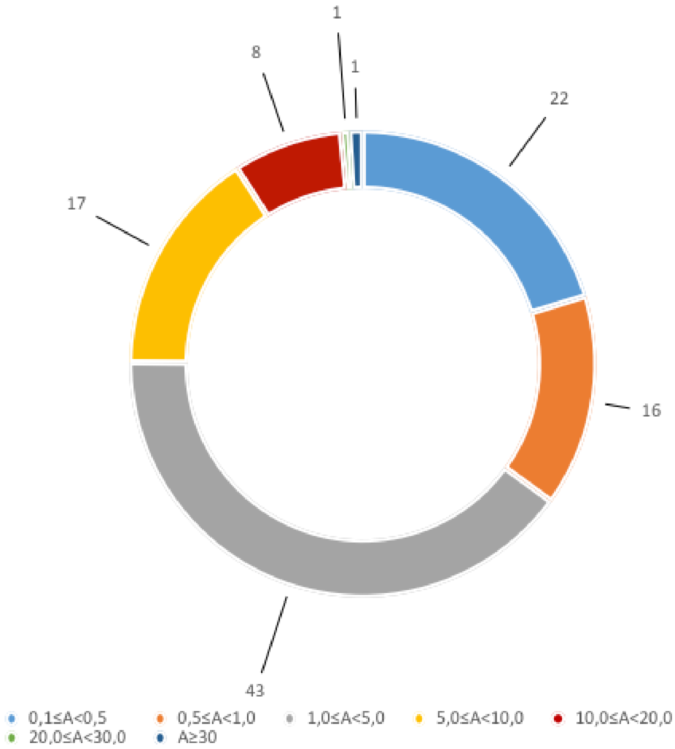

Figure 1 Average annual amount of runoff event with different intensity for ten years period of observation for observation station Oulu Oulunsalo Pellonpää."

The objective of this thesis is to develop the solution how to manage the stormwater and groundwater during the construction phase of the nuclear power plant of approximately 1.200MW at Hanhikivi headland in Pyhäjoki, Finland.

The construction site is located on the west coast of the Gulf of Bothnia, Cape Hanhikivi, Northern Ostrobothnia, in the municipality of Pyhäjoki. The population density of the area, adjacent to Cape Hanhikivi, is low. The nearest residential area is in the municipality of Pyhäjoki, located 6 km South-East of the survey area. The construction site is situated very close to the sea (shown in the Figure 2).

Figure 2 "A modified aerial image of nuclear power plant on the Hanhikivi headland." (Fennovoima 2014)

The construction area can be divided into 2 parts like shown in Figure 3 below:

1. The construction base is a complex of temporary buildings and facilities required for the construction of the nuclear power plant, as a temporary production, warehousing, office buildings, administrative and auxiliary facilities.
2. The area of the main pit – the territory of the future nuclear power plant.

The area of the main pit was considered in this thesis. As of June 2021, the topsoil has been removed from the entire territory of the pit. Blasting and excavation were carried out in the northern, central, and western sectors of the pit. The southern and eastern sectors are not developed, because the terrain is very rugged. The elevation marks of the bottom of the pit vary from +3.46 to -4.36, the average depth of the pit is being 2 m. The pit is filled with water with an admixture of loam and sandy loam. Next to the pit there are two settling ponds designed for the pumped water: ponds 93UGR and 94UGR. Injection to a depth of 20 m was carried out along the perimeter of the pit. A ring road has been built around the pit, the exit to the pit is organized in its south-western part. The works of pit arrangement for the main buildings and structures with auxiliary works up to the design elevation of -16.3 meters are planned to start at the end of 2021. The dimensions of the pit are 311 m x 427 m, the area of the pit is 132797 m2 and the volume of the pit is approximately 500 000 m3.

Figure 3 "Construction site (June 2021): 1 – The construction and installation base; 2 – the area of the pit." (Fennovoima. Photo of construction site 2021-2022)

Considering the volume of the pit and the fractured nature of the rock, a massive flow of seawater into the pit from the 0.000 elevation and below through cracks in the rock is expected, the issue of dewatering the pit is of paramount importance for carrying out work in the pit.

2.1 Existing system of collection and conveying stormwater and groundwater from the main pit area

The stormwater on construction site area is generated from water runoff from surface, runoff from buildings roofs, rain and snow melting water. The construction site area does not have a separate stormwater system. Water will be directed to ditches by the ground formatting. The surface of the construction site is not paved now.

Ponds 93UGR and 94UGR were built for dewatering during the excavation works. The ponds 93UGR and 94UGR are used for construction works, reactor and turbine island excavation works and tunnel works. Dewatering of the excavation pit will be done by pumping water from pit to settling ponds 93UGR and 94UGR. If the limit of maximum water level of settling ponds will exceed, water pumping shall be stopped immediately.

The surface water is collected and drained from the construction site by open roadside and collecting ditches. The ditches are arranged along temporary roads collecting water from the roads and sites. They convey the water to the complex of treatment facilities 93UGR and 94UGR. To treat the storm and groundwater, there is a complex of treatment facilities composed of sedimentation basins 93UGR and 94UGR, as well as a sand separator and oil separator. Further the treated drains come through a sampling well to be discharged to the Gulf of Bothnia via water drainage headers and channels.

The existing system for collecting and conveying groundwater and stormwater was designed and built following the requirements provided by the Environmental Permit limiting the discharge of treated wastewater into the Gulf of Bothnia in a volume of less than 250m^3/h. The settling ponds are designed and built to comply with the discharge limits to decrease the capacity of the water treatment facility The volume of the settling pond 93UGR is 2500m^3 and 94UGR - 2300m^3. The capacity of each treatment facility (sand and oil separator) is 144 m^3/h or 40 l/s.

Following chapter addresses issues related to environmental management, namely the requirements and restrictions provided by the environmental legislation of Finland.

3 ENVIRONMENTAL MANAGEMENT

This section outlines the principals of environmental management to control, mitigate and prevent potential negative environmental impacts associated with the construction of Hanhikivi-1 NPP. An environmental management plan was developed to ensure that the environmental issues are properly considered during the construction phase and that negative environmental impacts are minimized or prevented. The objective of this document is to outline the implementation of the environmental management and legal requirements during the construction phase. It will provide best practice in environmental matters and ensure that the standards for environmental protection are maintained at the highest levels. It will ensure the systematic planning and implementation of all aspects of the work scope relating to environmental management. The environmental management plan is developed within the requirements of ISO 14001:2015. Mitigation measures, included in this Environmental Management Plan and respective procedures comply with the applicable Finnish environmental legislation, national target programs and international commitments. (JSC “Concern Titan-2” 2021)

The environmental impacts of the activities during Hanhikivi-1 NPP construction project at the primary stage fall into the following types:

- emissions to the atmosphere.
- discharge of pollutants into water courses.
- measurement of seawater turbidity.
- environmental impacts when handling wastes.
- impacts of soil removal and excavation works (habitats loss).
- use of natural resources (water, thermal and electric energy).
- physical environmental impacts (noise, heat, groundwater).
- accidents and abnormal situations causing environmental impacts.

In accordance with the objectives of this thesis, mitigation measures such as monitoring of the groundwater level and monitoring of the quantity and quality of water discharged into the Gulf of Bothnia will be considered in more detail.

3.1 Water and environmental permits

Water Act (587/2011) regulates permits for water economy projects. A permit pursuant to Water Act is required for the hydraulic construction works and structures within water systems. A permit according to Water Act is also necessary for operations that include leading water out of a water system. The water permit authority is the Regional State Administrative Agency of Northern Finland.

The Environmental Protection Act is applied for watercourse pollution issues. Due to the fact, that wastewater, as well as groundwater and stormwater formed during the construction phase, is treated, and conveyed directly into the water body, it is crucial to obtain an environmental permit. According to Chapter 4, section 27 of Environmental Protection Act an environmental permit is required for: *"an activity that may cause pollution of a water body, and the project in question is not one requiring a permit under the Water Act*". (Ministry of the Environment)

Furthermore, the construction site has functions that require permits in accordance with the Environmental Protection Act. This includes a rock crushing plant, which is utilized for crashing exploded rock soil from the main pit. According to Annex 1, Table 1 of Environmental Protection Act, an environmental permit is also required for: *"Mining of ores or minerals, or excavation of soil".* The Environmental permit (1/15/2016 / PY-YL1 / 2016) was granted by the Environmental Authority of Pyhäjoki Municipality. (Ministry of the Environment)

The Environmental Permit (1/15/2016 / PY-YL1 / 2016) was requested for the development of rock for the construction of a pit for the main buildings and structures of Hanhikivi-1 NPP and for crushing the rock mass obtained during the development of the pit into crushed stone. (Environmental Authority of Pyhäjoki Municipality 2016)

The development of the pit and the conversion of rock mass into crushed stone means drilling holes in the rock with a drilling rig, laying an explosive charge and blowing up the rock. After the explosion, the rock mass is transported by an excavator to dumpers and taken to temporary storage site of the rock mass. The rock mass obtained during the development of the main pit will be processed into crushed stone of different fractions. Before crashing, over-sized fragments of rock need to be broken into smaller stones with the help of a hydraulic hammer, which is acceptable for a crushing plant. The crushed stone will be stored in fractions at the site next to the crushing plant, from where it will be used in the structural layers of facilities on the construction site, such as embankments of road zones, backfilling etc. Settling ponds 93UGR and 94UGR will be used for dewatering during the development of the pit for the main buildings and structures.

The area of the development is about 17 ha. The development will be carried out up to the levels of -22.0 m. The volume of rock soil will be about 500,000 m3.

4 ASSESSMENT METHODS

Stormwater and groundwater generated on construction site can be divided into the following types: groundwater seeping into the pit through rock; rainwater - direct precipitation into the pit and surface stormwater flow, which trapped by various types of surfaces. Each of these types of wastewaters will be considered in a separate chapter of this thesis.

4.1 Assessment of groundwater amount

The determination of the amount of groundwater entering the pit is based on a geological study conducted at the end of 2020. The obtained results of geological survey are not interpreted in this chapter but used in further assessment of the amount of stormwater generated at the construction site. The chapter describes the process of this geological study, initial data, results, and assumptions.

The evaluation of groundwater amount is based on a ground water flow model. The groundwater flow model was established for Hanhikivi-1 NPP research area. The result of the project is a 3D groundwater flow model, i.e., a mathematically simulated description of groundwater flow as a function of time, and visual observation for flow. The model was used to make various simulations of how groundwater flow at the site changes in different situations. (Pohjatekniikka Oy 2020)

The calibration of the groundwater model is based on changing the initial values of the model, so that the results, given by model, correspond as closely as possible with those observed in the nature. The calibration of the groundwater model was mainly carried out by changing two key parameters of bedrock. The variable parameters were hydraulic conductivity and specific yield. The most important data for calibration have been obtained from two pumping tests groundwater elevation measurements conducted outside and inside the pit. (Pohjatekniikka Oy 2020, Eurofins Ahma Oy 2019-2021)

4.1.1 Pumping tests

According to the geological study, the pumping tests installation works started at Hanhikivi-1 NPP site on line 1 on 13.10.2020. Pump and monitoring loggers were installed in well PW1 and in all line 1 monitoring wells (6 pcs.). Site area map in Figure 4, presents the location of the line 1 and line 2 pumping and monitoring wells. (Pohjatekniikka Oy 2020)

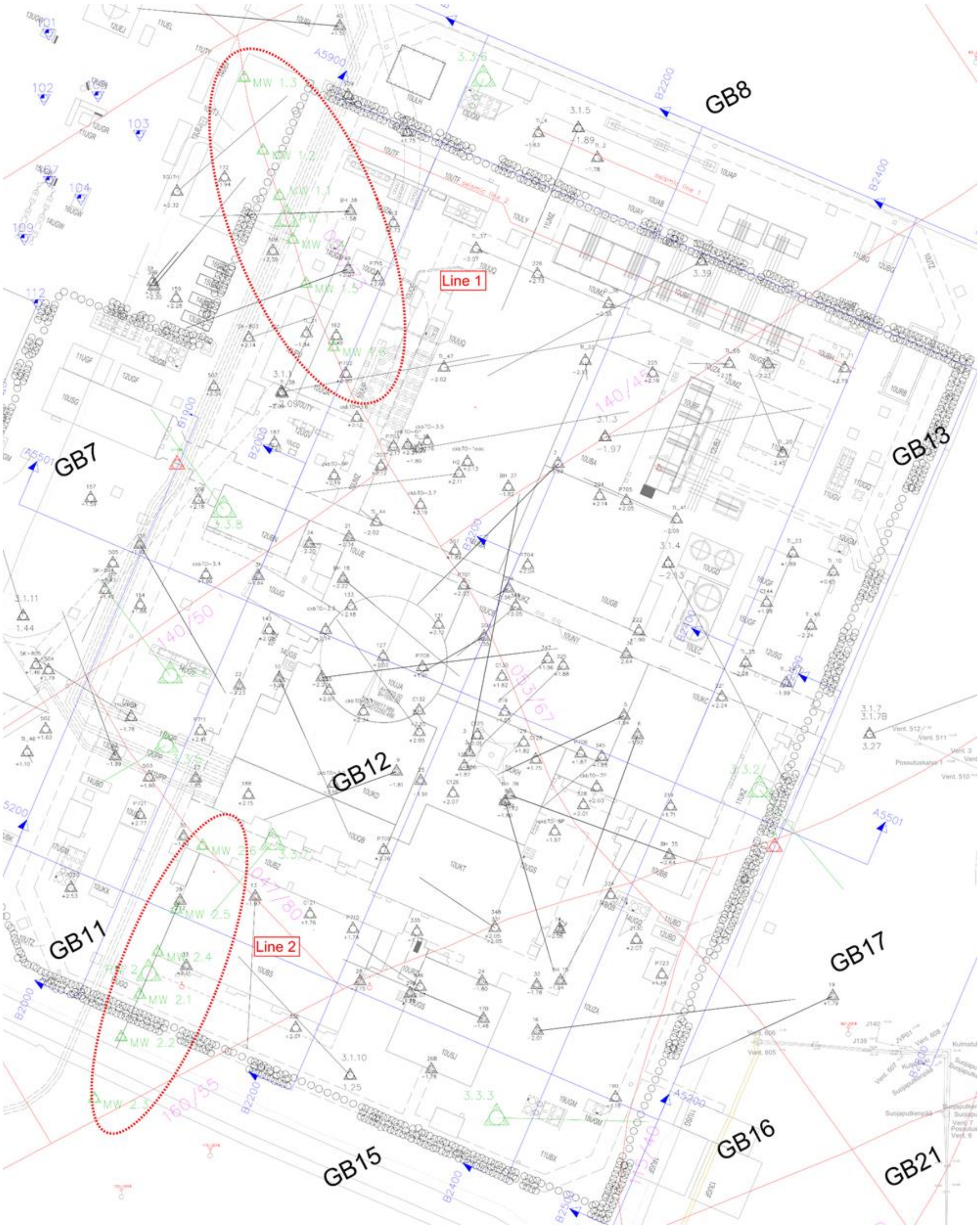

Figure 4 Location of Line 1 and Line 2 pumping wells (PW's) and monitoring wells (MW's) in green colour and rounded by red dashed line (Pohjatekniikka Oy 2020)

After the test pumping with recovery test of the line 1 the pump and monitoring system was moved to line 2, which was tested in a similar way. The test pumping period was 72 hours of continuous pumping with a constant pump rate. During the pumping all installed piezometers were monitoring the change of the water levels in pre-stated intervals both in the pumping wells and monitoring wells. The water flow was monitored during the whole pumping period as well. Electric conductivity and ground water temperature was monitored from the pumped water flow during the pumping period in both wells. The pumps were stopped after the pumping period of 72 hours and recovery period of 24 hours started with the monitoring of the ground water level. During the recovery period, water levels were monitored following the pre-stated program intervals.

4.1.2 Groundwater elevation measurement

According to Eurofins Ahma Oy, 2019-2021 program, monitoring the groundwater levels and quality on the construction site were started in October 2019, 16 groundwater monitoring wells was installed in August and September 2019 (shown in the Figure 5).

Figure 5. Location of groundwater monitoring wells around construction area (Eurofins Ahma Oy, 2019-2021)

Pressure and temperature sensors were installed into all monitoring wells. Loggers were suspended in the wells on cables, and they were set to record pressure at 24-hour intervals. The level logger records automatically and continuously the fluctuations in water pressure, which are compensated by the Barologger recordings (atmospheric pressure), and results are expressed in meters. The software automatically produces compensated data files. The sampling personnel verified the reliability of the logger recordings after the initial logger installations by comparing the logger recordings to manually measured water levels. (Eurofins Ahma Oy, 2019-2021)

Water levels were measured every time the logger was read. The sampling of groundwater was conducted four times a year for the groundwater quality assessment. Water levels were measured, and the samples were collected by certified sampling personnel and the water samples were submitted to Eurofins laboratories and analysed using standardized methods. Samples from all wells were analysed for 146 variables field measurements (level, temperature, redox) which are part of the parameters. (Eurofins Ahma Oy, 2019-2021)

4.1.3 Hydrological survey results

The groundwater model is a simplified mathematical description of groundwater flow in soil and bedrock. The conceptual model serves as a basic description of the model, which is then exported to the modelling program in mathematical form. The conceptual model includes layered information of the following zones: solid bedrock, fracture zones, soil types, grouting walls; ·sea (constant water elevation). After the conceptual model is exported to the modelling program, it is transformed into a mathematical form, a grid. The groundwater model consists of almost 500000 cells, all of which are fed the parameters affecting the groundwater flow. The parameters describe the properties of the bedrock or soil represented by that cell, in terms of recharge, leaked and stored groundwater. (Pohjatekniikka Oy 2020)

Based on the results obtained during pumping tests and groundwater measurement, the value of hydraulic conductivity and specific yield were changed in each of the 500000 groundwater model cells. The calculation of the amount of water inflow into the pit was made for the situation of 125 days after the pit has been excavated to its final elevation. The results present almost a steady-state situation. (Pohjatekniikka Oy 2020)

According to geological study (Pohjatekniikka Oy 2020), the model evaluates the total inflow to the pit to be 1700 m^3/d. The rate of drainage 1.700 m^3/d is the maximal rate of drainage that is achieved in simulation day 100 after two days of heavy rain (shown in the Figure 6). Seepage water consists of infiltrated portion of rainwater, water infiltrated to soil and bedrock at the coast, and water flow in soil and bedrock along land border of the model on its eastern edge.

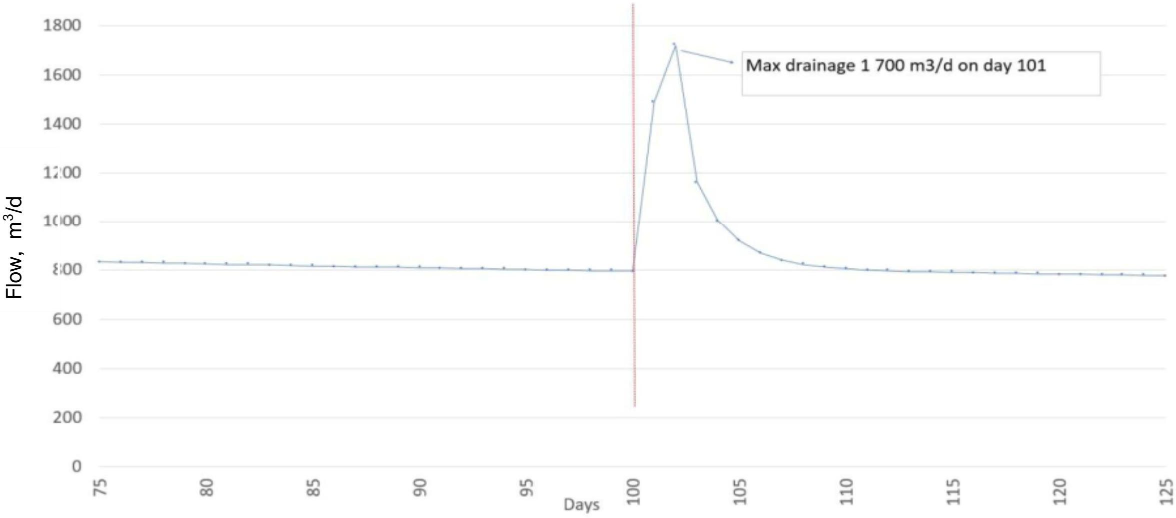

Figure 6 Graph of daily forecasted drainage between simulation days 75-125 (Pohjatekniikka Oy 2020)

In the groundwater model of 2020, the infiltration rate due to precipitation is for the first 99 days of simulation $2.537*10^{-9}$ m/s (=80 mm/year), which constitutes 15% of average precipitation 533 mm/year. On simulation days 100 and 101 a rain with the intensity of 7 l/s*ha and duration of 24 hours was applied to the model area, which equals 60.48 mm/d. Such intensity for a 24-hours rain statistically occurs in Finland only once per every 5 years. (Pohjatekniikka Oy 2020)

Our data indicates that the amount of water inflow into the pit is 1700 m^3/d. This quantity does not consider such criteria as direct precipitation into the pit and surface flow, which is trapped by various types of surfaces (gravel, asphalt).

4.2 Assessment of rainwater amount

Estimation of the amount of rainwater entering the pit when it rains for 24 hours, with a frequency of 3, 5.10, 50, 100 years, as well as examination the capacity of settling ponds for the possibility of processing precipitation of a given intensity will be performed by using Bentley Sewer GEMS software.

4.2.1 Input data for simulation

Simulation of pit, settling ponds 93UGR and 94UGR

The pit is considered as a pond for storing stormwater. To describe the pit condition parameter Area vs. Elevation was used. The Elevation vs. Area table represents the grading plan contour information for the pond. The area column represents the water surface area corresponding with water surface elevation in the same row in the table. Bentley Sewer GEMS will calculate the cumulative volume at each given elevation, based on the given Elevation vs. Area data. The pit area has a difficult spatial configuration with bottom of various elevation. To input data “Area vs. Elevation” the pit was divided to parts in different elevation. The critical meaning for computing is the deepest pit parts from -22.00 to -10.00, the areas located higher than -10.00 do not have a significant impact on simulation (shown in the Figure 7). To define the parameters “Elevation vs. Area” for settlings ponds 93UGR and 94UGR was built the 3D models based on geodetic survey as shown in the Figure 8.

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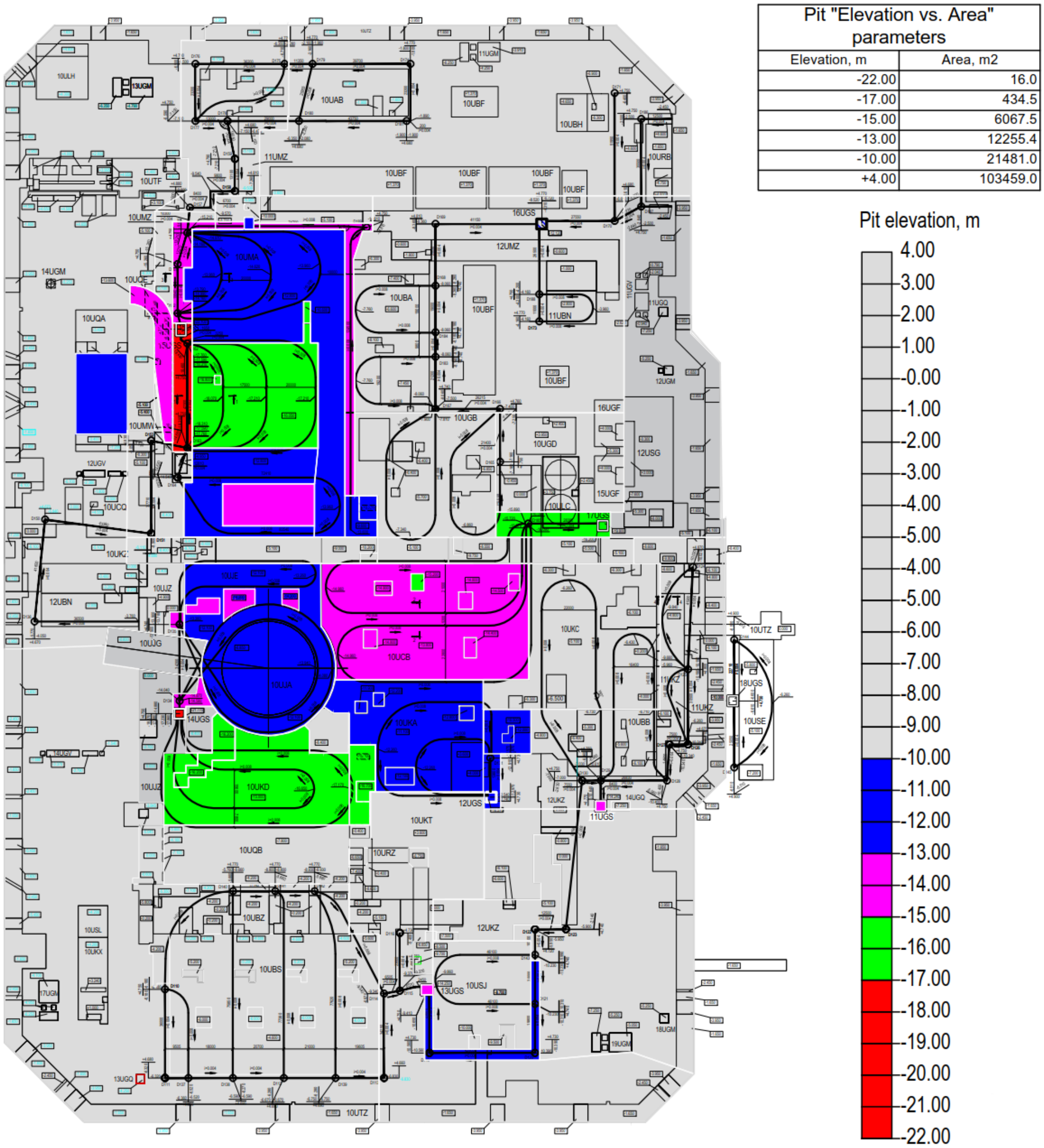
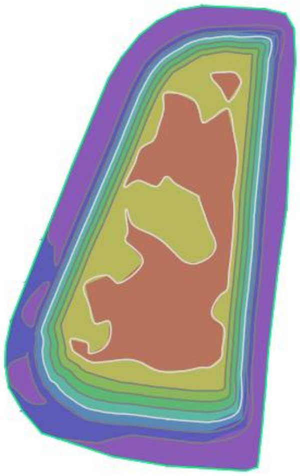


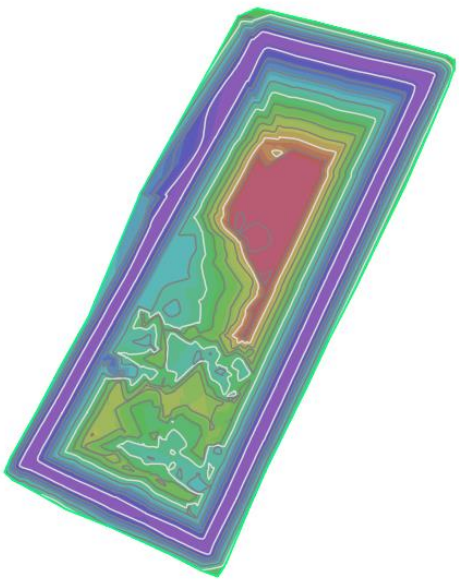
Pit "Elevation vs. Area" parameters	
Elevation, m	Area, m2
-22.00	16.0
-17.00	434.5
-15.00	6067.5
-13.00	12255.4
-10.00	21481.0
+4.00	103459.0

Figure 7. Pit “Elevation vs. Area” parameters



Settling pond 93UGR

Ranges of elevation, m				
# range	Lower limit, m	Upper limit, m	Color	Area 2D м2
1	-1.00	-0.50		0.00
2	-0.50	0.00		861.85
3	0.00	0.50		695.01
4	0.50	1.00		211.29
5	1.00	1.50		222.56
6	1.50	2.00		233.84
7	2.00	2.50		245.11
8	2.50	3.00		405.10
9	3.00	3.50		775.95



Settling pond 94UGR

Ranges of elevation, m				
# range	Lower limit, m	Upper limit, m	Color	Area 2D m2
1	-1.05	-1.00		22.89
2	-1.00	-0.20		323.47
3	-0.20	0.60		205.67
4	0.60	2.50		1733.43
5	2.50	3.35		964.07
6	3.35	4.50		7.04

Figure 8. Settling ponds 93UGR and 94UGR "Elevation vs. Area" parameters

Precipitation

As a precipitation data for simulation, the design storms with an accumulation period of 24 hours for 5, 10, 50, 100 years return period used open data. The database of design storms is based on radar measurements from Finland in 2013–2016 obtained in framework of URCLIM project (Advance on Urbane Climate Services) of the Finnish Meteorological Institute. Runoff hydrographs are presented below. (shown in the *Figure* 9, *Figure* 10, *Figure* 11, *Figure* 12) (FMI. Database of design storms in Finland, 2013-2016)

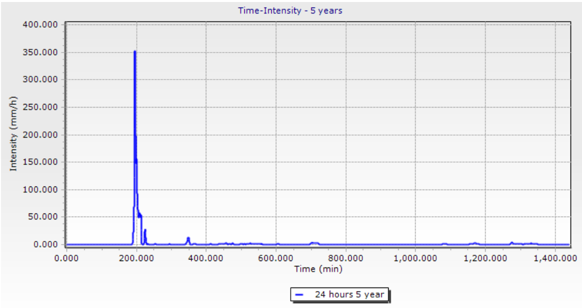


Figure 9. *Runoff hyetograph 24 hours duration, return period 5 years*

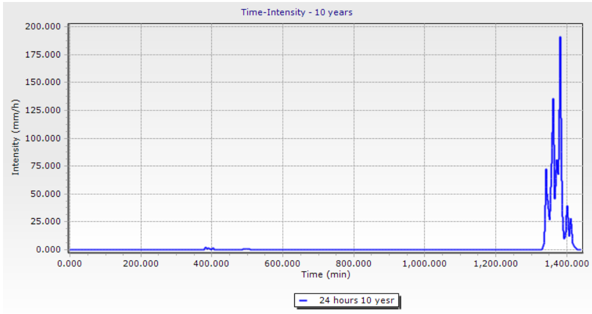


Figure 10 *Runoff hyetograph 24 hours duration, return period 10 years*

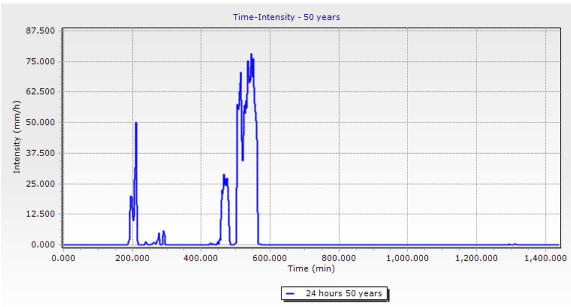


Figure 11. *Runoff hyetograph 24 hours duration, return period 50 years*

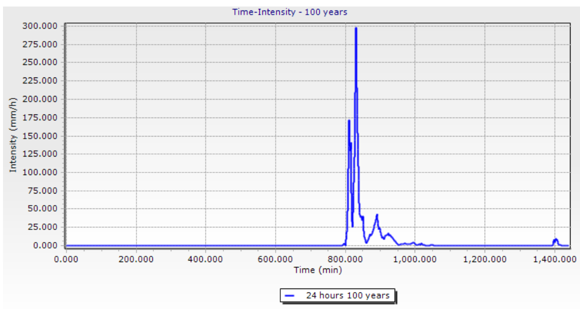


Figure 12. *Runoff hyetograph 24 hours duration, return period 100 years*

Other initial data and assumptions while the computing

- Pit is considered as a pond, due to complicated spatial configuration with different elevation of the bottom, the area of the pit is calculated in the certain range of elevation that allow to align the configuration to a simpler form.

- The direct precipitation to the pit is considered as catchment with an impervious percentage of 100%, the inflow of groundwater into the pit in the volume of 1700 m3/day is accepted as a uniform fixed inflow during the day.
- Due to the fact that inflow of groundwater 1700 m3/day is estimated only for rain event with the return period of 5 years (shown in chapter 4.1.3 Hydrological survey results), this value is used for all computing cases 5, 10, 50, 100 years return period.
- The ditches along the road are accepted with trapezoidal cross section, bottom height is 0.5m and the material is concrete.
- To organize the drainage of ground and rainwater from the pit, pumps are provided, pumping water from the pit flows into the ponds 94UGR and 93UGR. The pumps are accepted on the condition of preventing the water level in the pit from rising above the -17.0 m elevation. This elevation mark is accepted due to the spatial configuration of the pit, namely at the elevation bellow -17.0 m concrete elevation works are not done, therefore this part of the pit may be flooded during heavy rain.
- The outflow pipes from ponds 93UGR and 94UGR are limited in flow, no more than 40 l/s (144 m3/h) – capacity of existing water treatment facility.

4.2.2 Results of computing

The computing case is the simulation of precipitation of different intensity and repeatability on the considered area, providing that the developed pit is up to the design elevation, because the point of view of preventing flooding of the pit this case is the most critical for several reasons:

1. When the excavation was developed up to the design elevation, the greatest inflow of groundwater will be observed due to the increase the area of the pit walls through which ground water seeped.
2. The most reliable groundwater pumping system is required to prevent the flooding of the pit, because after the end of the blasting work, the installation of concrete foundation for the main buildings and structures of the nuclear power plant will be carried out. When performing these works, flooding of the pit above the -17.0 m mark is not allowed.

The roadside ditches along the roads are provided to organize the drainage of surface rainwater from the adjacent territory. The vertical layout of the roadside ditches is made considering the existing terrain. Part of the surface rain runoff is diverted to the existing pond 93UGR because the elevation of the existing inflow pipe into the pond allows the surface runoff to be diverted by gravity from part of the territory. Because the 94UGR pond is located above the marks of the adjacent territory, a third pond (Design Pond) is provided for collecting surface rainwater.

The parameters of main units for design cases with different intensity and repeatability that have been observed while computing are shown in table in figures: for catchments (TABLE 1, TABLE 2, TABLE 3, TABLE 4), for ponds (TABLE 5, TABLE 6, TABLE 7, TABLE 8), for pumps (Figure 13, Figure 14, Figure 15, Figure 16).

The graphic results of the simulation of different intensity precipitation and repeatability on the considered area shown in the APPENDIX 1

Label	Runoff Method	Loss Method	Scaled Area (m²)	Flow (Maximum) (L/s)	Volume (Total Runoff) (m³)	Area (Unified) (m²)
Direct precipitationin pit	Unit Hydrograph	Constant Loss Rate	164,047	1,228.06	6,921.0	164,047
Fennovoima's area	Unit Hydrograph	Horton	48,449	324.17	1,062.5	48,449
Gravel area mixed purpose	Unit Hydrograph	Horton	43,809	293.13	960.8	43,809
North part of ring road	Unit Hydrograph	Horton	7,370	49.31	161.6	7,370
Stone crushing site	Unit Hydrograph	Horton	33,170	221.94	727.5	33,170
Fingrid area	Unit Hydrograph	Horton	57,976	386.94	1,268.2	57,976

TABLE 1. Scenario: Hydrograph 24 hours 5 years. Catchment table.

Label	Runoff Method	Loss Method	Scaled Area (m²)	Flow (Maximum) (L/s)	Volume (Total Runoff) (m³)	Area (Unified) (m²)
Direct precipitationin pit	Unit Hydrograph	Constant Loss Rate	164,047	1,603.40	6,684.6	164,047
Fennovoima's area	Unit Hydrograph	Horton	48,449	388.76	1,103.1	48,449
Gravel area mixed purpose	Unit Hydrograph	Horton	43,809	351.53	997.4	43,809
North part of ring road	Unit Hydrograph	Horton	7,370	59.14	167.8	7,370
Stone crushing site	Unit Hydrograph	Horton	33,170	266.16	755.2	33,170
Fingrid area	Unit Hydrograph	Horton	57,976	460.02	1,303.8	57,976

TABLE 2. Scenario: Hydrograph 24 hours 10 years. Catchment table.

Label	Runoff Method	Loss Method	Scaled Area (m²)	Flow (Maximum) (L/s)	Volume (Total Runoff) (m³)	Area (Unified) (m²)
Direct precipitationin pit	Unit Hydrograph	Constant Loss Rate	164,047	1,330.88	8,367.1	164,047
Fennovoima's area	Unit Hydrograph	Horton	48,449	369.78	1,485.4	48,449
Gravel area mixed purpose	Unit Hydrograph	Horton	43,809	334.38	1,343.2	43,809
North part of ring road	Unit Hydrograph	Horton	7,370	56.25	226.0	7,370
Stone crushing site	Unit Hydrograph	Horton	33,170	253.17	1,017.0	33,170
Fingrid area	Unit Hydrograph	Horton	57,976	435.41	1,745.2	57,976

TABLE 3. Scenario: Hydrograph 24 hours 50 years. Catchment table.

Label	Runoff Method	Loss Method	Scaled Area (m²)	Flow (Maximum) (L/s)	Volume (Total Runoff) (m³)	Area (Unified) (m²)
Direct precipitationin pit	Unit Hydrograph	Constant Loss Rate	164,047	2,344.76	12,769.9	164,047
Fennovoima's area	Unit Hydrograph	Horton	48,449	667.08	2,441.2	48,449
Gravel area mixed purpose	Unit Hydrograph	Horton	43,809	603.21	2,207.4	43,809
North part of ring road	Unit Hydrograph	Horton	7,370	101.48	371.3	7,370
Stone crushing site	Unit Hydrograph	Horton	33,170	456.72	1,671.3	33,170
Fingrid area	Unit Hydrograph	Horton	57,976	794.33	2,898.1	57,976

TABLE 4. Scenario: Hydrograph 24 hours 100 years. Catchment table.

Label	Hydraulic Grade (m)	Hydraulic Grade (Maximum) (m)	Flow (Total in Maximum) (L/s)	Storage (Maximum) (m³)
94UGR	-1.00	2.15	402.03	2,269.5
93UGR	-1.00	1.82	789.44	3,459.7
Pit	-22.00	-17.76	1,228.06	820.4
Design pond	0.50	2.12	1,003.67	3,695.7

TABLE 5. Scenario: Hydrograph 24 hours 5 years. Pond table.

Label	Hydraulic Grade (m)	Hydraulic Grade (Maximum) (m)	Flow (Total in Maximum) (L/s)	Storage (Maximum) (m³)
94UGR	-1.00	1.81	422.15	1,699.9
93UGR	-1.00	1.46	943.89	2,726.2
Pit	-22.00	-16.51	1,602.64	1,668.9
Design pond	0.50	2.42	1,184.99	4,526.8

TABLE 6. Scenario: Hydrograph 24 hours 10 years. Pond table.

Label	Hydraulic Grade (m)	Hydraulic Grade (Maximum) (m)	Flow (Total in Maximum) (L/s)	Storage (Maximum) (m³)
94UGR	-1.00	2.39	413.30	2,772.9
93UGR	-1.00	2.19	885.55	4,291.0
Pit	-22.00	-17.14	1,326.78	1,067.6
Design pond	0.50	2.61	1,113.25	5,097.4

TABLE 7. Scenario: Hydrograph 24 hours 50 years. Pond table.

Label	Hydraulic Grade (m)	Hydraulic Grade (Maximum) (m)	Flow (Total in Maximum) (L/s)	Storage (Maximum) (m³)
94UGR	-1.00	3.16	431.93	4,808.9
93UGR	-1.00	3.10	1,454.83	6,672.3
Pit	-22.00	-15.74	2,335.24	3,922.6
Design pond	0.50	3.34	1,700.92	7,773.0

TABLE 8. Scenario: Hydrograph 24 hours 100 years. Pond table

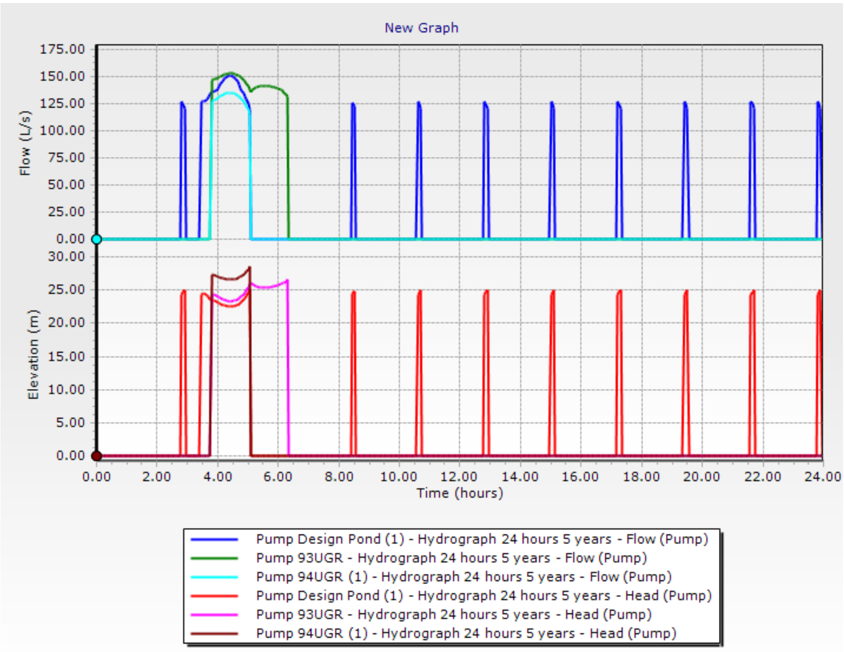


Figure 13. Scenario: Hydrograph 24 hours 5 years. Pumps flow and head graph.

Figure 14. Scenario: Hydrograph 24 hours 10 years. Pumps flow and head graph.

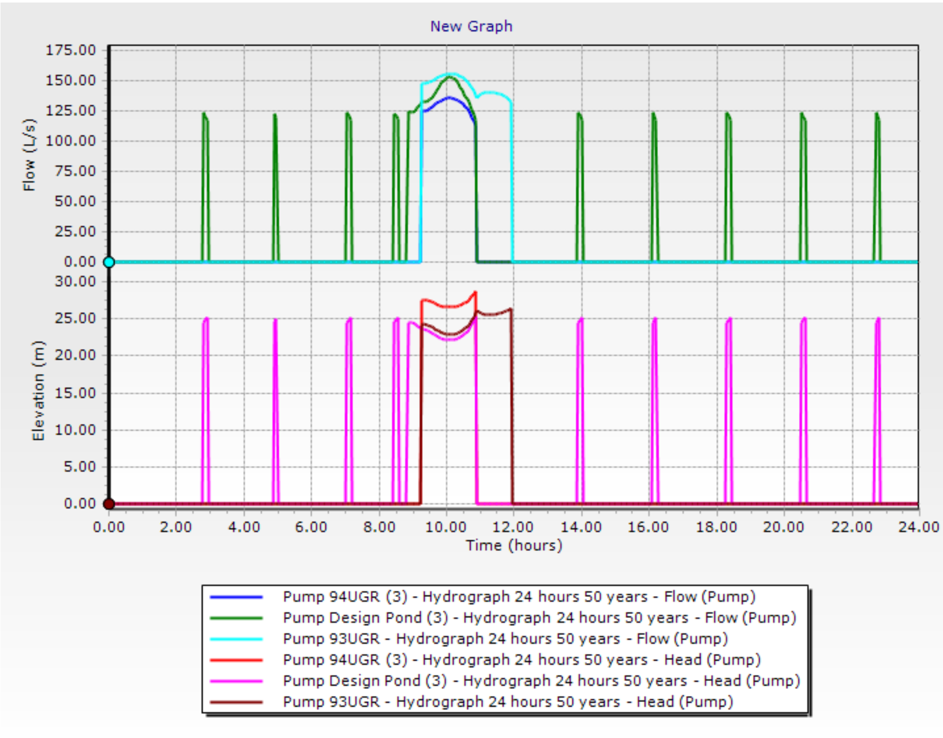


Figure 15. Scenario: Hydrograph 24 hours 50 years. Pumps flow and head graph.

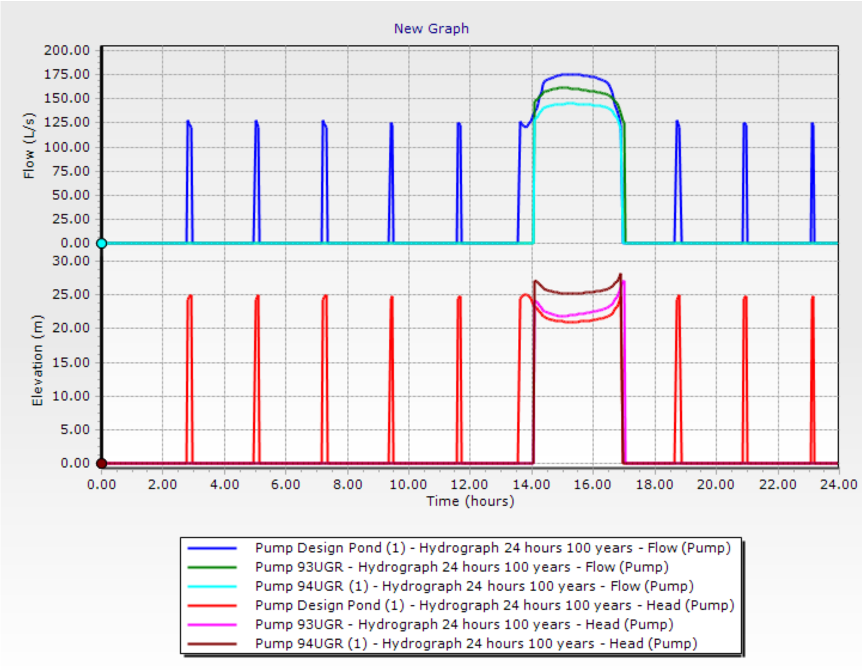


Figure 16. Scenario: Hydrograph 24 hours 100 years. Pumps flow and head graph.

As shown in TABLE 1, TABLE 2, TABLE 3, TABLE 4 the total maximum flow of runoff for the considered area is: 2503.5 l/s for 5 years repeatability rain; 3129.01 l/s for 10 years repeatability; 2779.87 l/s for 50 year repeatability; 4967.58 l/s for 100 years repeatability. While the precipitation levels of rainfall are: 53.2 mm for 5 years repeatability rain, 72.2mm for 10 years repeatability, 79.04mm for 50 years repeatability, 109.58mm for 100 years repeatability. By ccomparing the results of the maximum flow of rain with 10- and 50-years repeatability to the precipitation amount for rain with the same repeatability even though precipitation amount is increasing from 72.2mm to 79.04mm for the rain with less possibility, the maximum flow is decreasing from 3129.01 l/s to 2779.87 l/s. This is since only a part of the rainfall occurring on the area becomes runoff, which is considered while computing.

As shown in *Figure* 10 and *Figure* 11 runoff hydrograph with a return period of 10 years has a higher peak intensity, than hyetograph with a return period of 50 years, which has less peak intensity, but longer duration. This means that with rain of longer duration and less intensity, part of the precipitation amount will be compensated by the filtration properties of the soil, and therefore less rain will turn into runoff. This pattern is considered when calculating using Hortonian infiltration models.

5 CONCLUSION

The objective of this thesis is to develop the management system of the stormwater and groundwater during the construction phase of Hanhikivi-1 NPP.

The main purpose of the thesis was to check the sufficiency of the volume of the 93UGR and 94UGR ponds with limited discharge into the Gulf of Bothnia, no more than 250 m3/h during rain event of varying intensity and repeatability for 5, 10, 50 and 100 years.
To organize rain and groundwater management system at the construction site, the following activity must be taken:

- Grad and level of adjacent area to the main pit with the construction of roadside ditches on both sides of the temporary ring road. The results of the calculation showed that the construction of a single-slope road with a roadside ditch on its one side is not enough. The calculation is made for trapezoidal concrete roadside ditches with a bottom width of 0.5 m and height of 0.5 m.

- Provide for a new settling pond and a complex of treatment facilities with the discharge of purified water into the Gulf of Bothnia, which requires amendments to the current environmental permit. The dimensions of the settling pond and treatment facilities depend on the chosen reliability of the system; namely, for the rain of what intensity and frequency (5. 10, 50, 100 years) the system for collecting and diverting rain and groundwater will be designed.

- Provide the groups of drainage pumps to pump water into the existing settling ponds 93UGR and 94UGR and a new settling pond to divert groundwater and rainwater from the pit. Considering the fact that the installation of foundations for NPP buildings and structures does not allow flooding of the pit above the level of -17.0 m, it is necessary to detamine the reliability of the system, namely, drainage pumps should be selected for the rain of a certain intensity and frequency. In addition, the calculation is made for an inflow of groundwater in the amount of 1700 m3/day, this value is determined for the rain with a frequency of 1 time in 5 years (Pohjatekniikka Oy 2020). Due to the lack of such data for the rain with a lower probability, this value of groundwater inflow is also used for the design cases for the rain with a frequency of 10, 50, 100 years. Therefore, the amount of rainwater inflow with less intensity should be specified.

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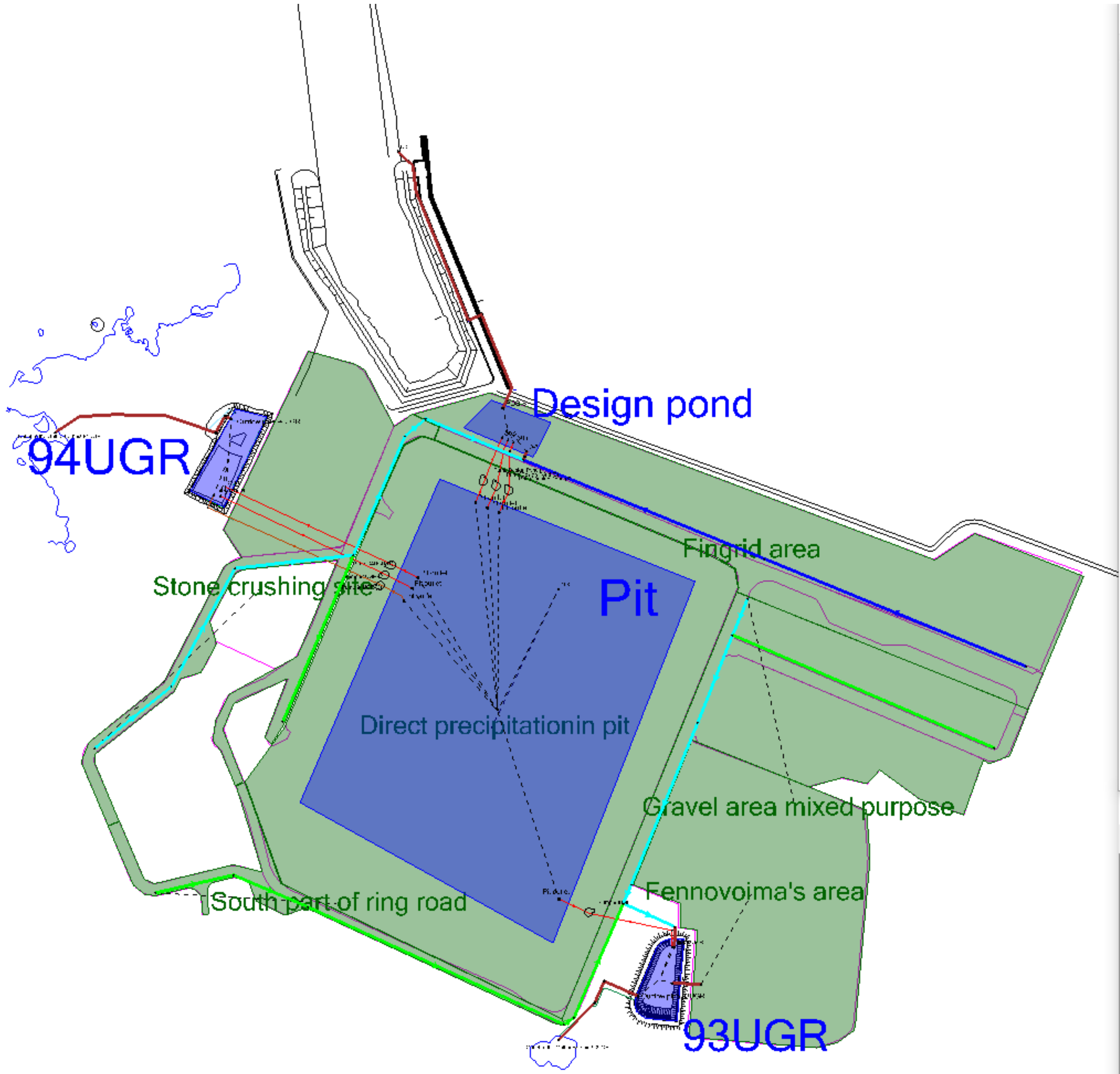
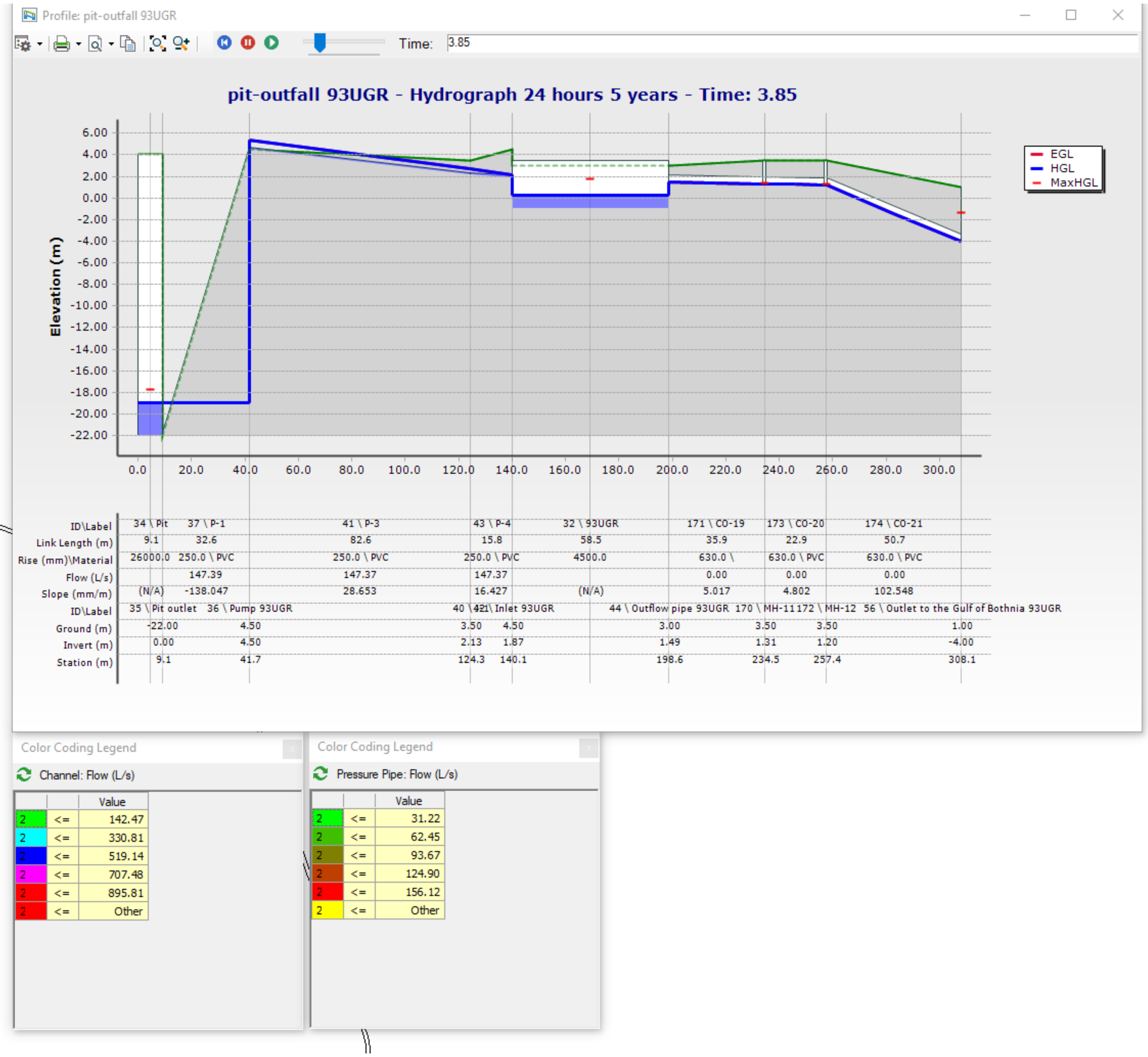
APPENDIX 1 COMPUTING SCHEMES (PROFILES AND LAYOUTS) OF DESIGN AREA

PROFILE AND LAYOUT. ROUTE: PIT - 93UGR - OUTFALL TO THE GULF OF BOTHNIA

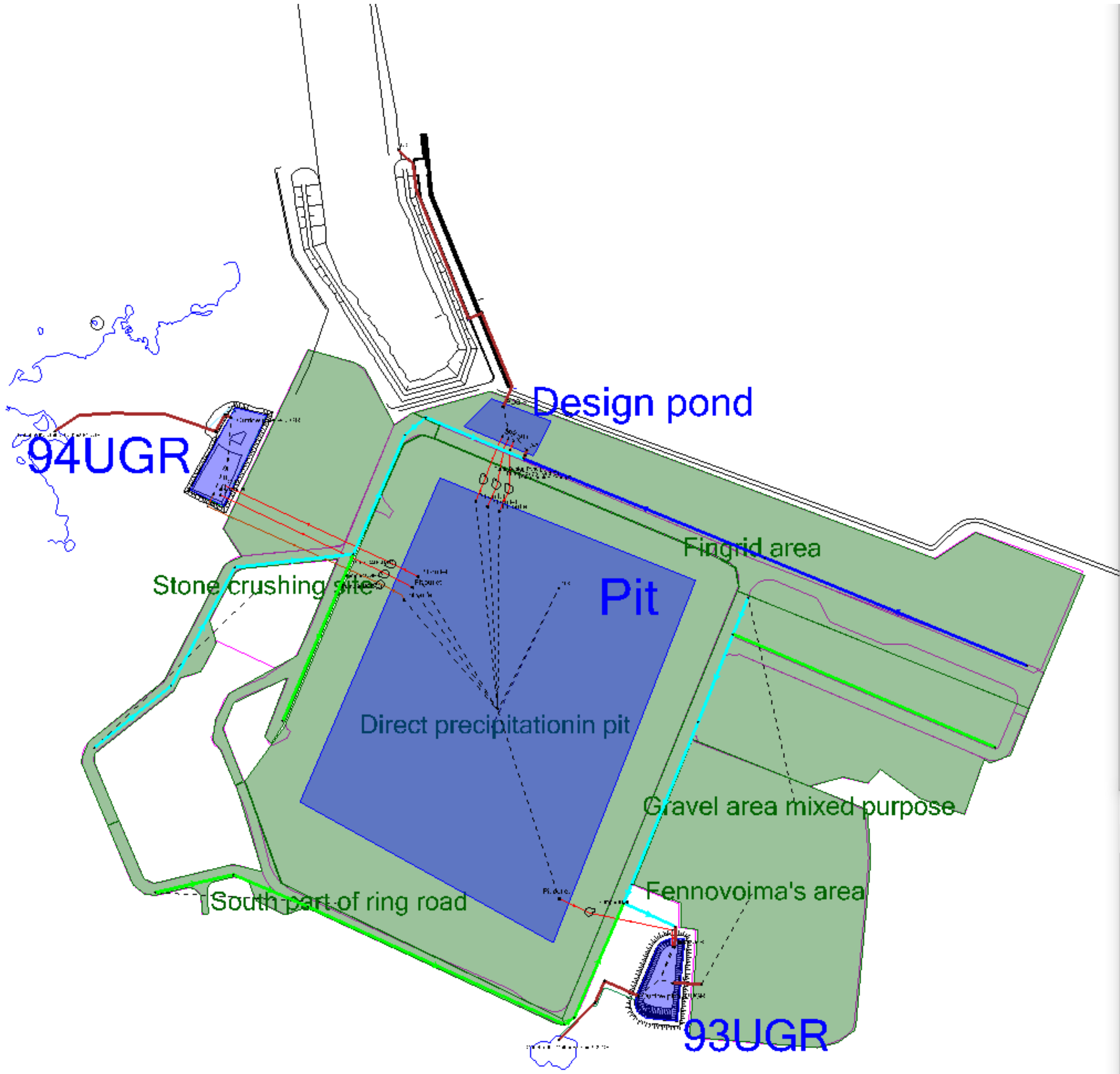
CALCULATION CASE: 5 YEARS RETURN PERIOD RAIN

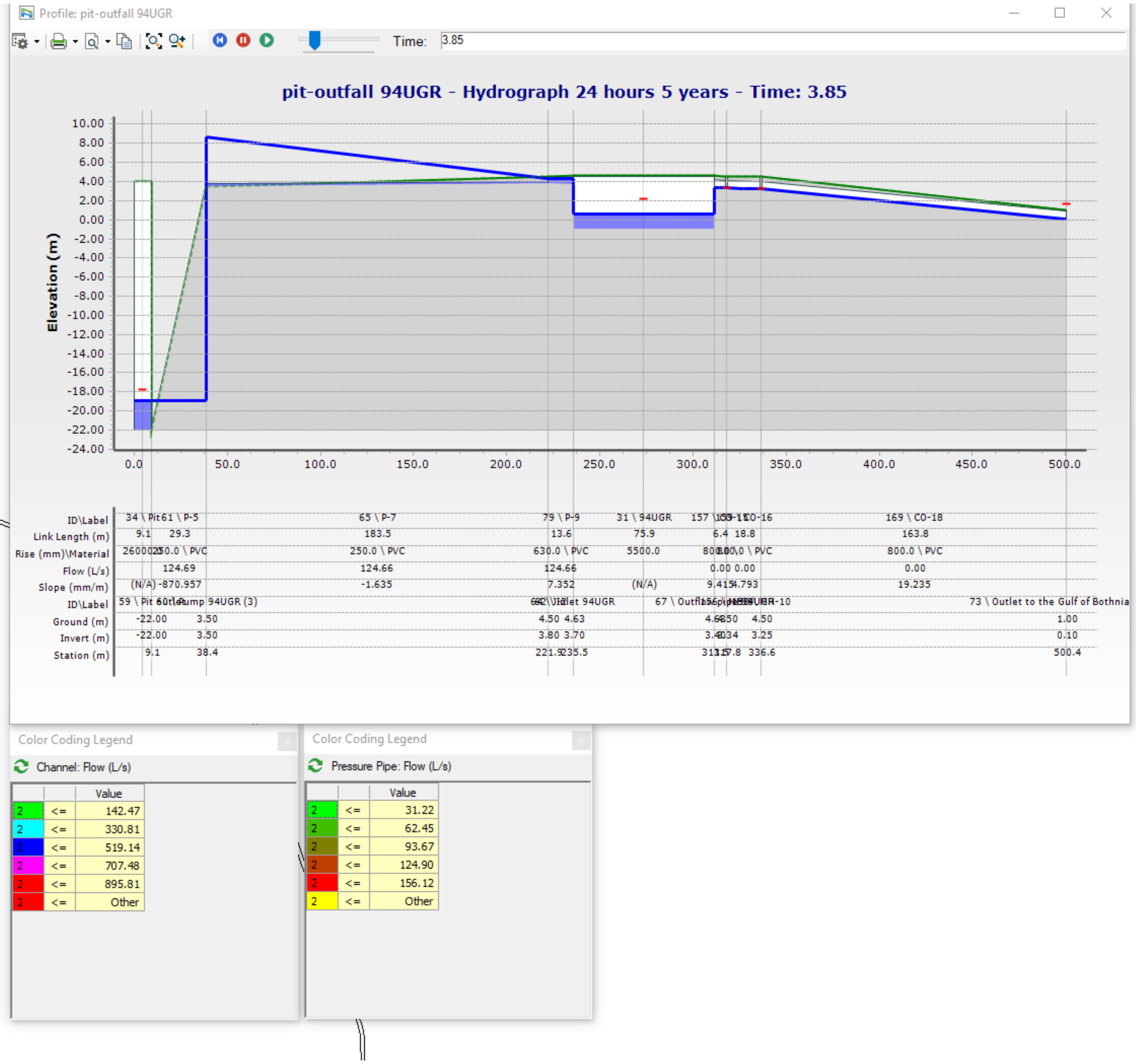




PROFILE AND LAYOUT. ROUTE: PIT - 94UGR - OUTFALL TO THE GULF OF BOTHNIA

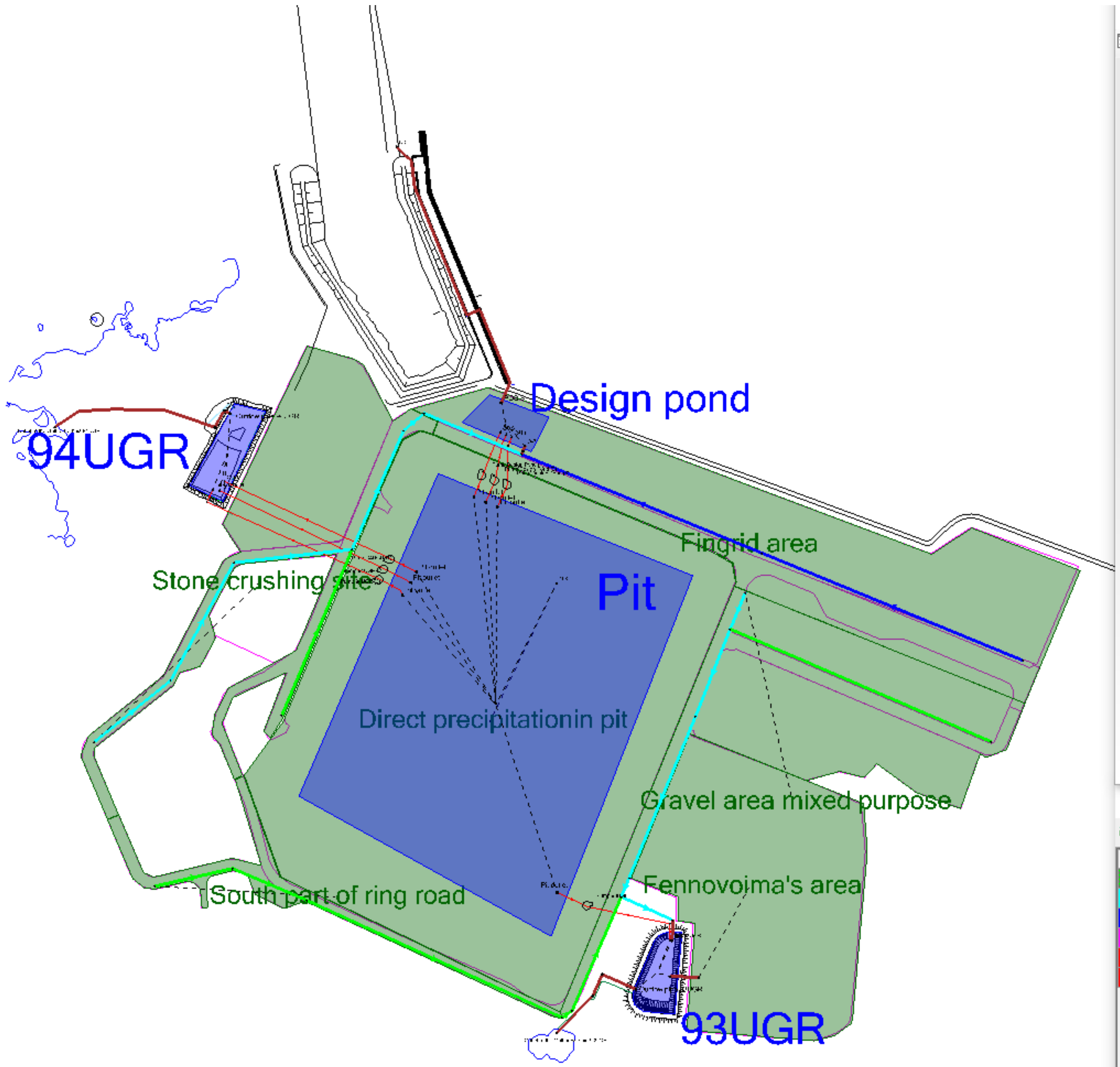
CALCULATION CASE: 5 YEARS RETURN PERIOD RAIN

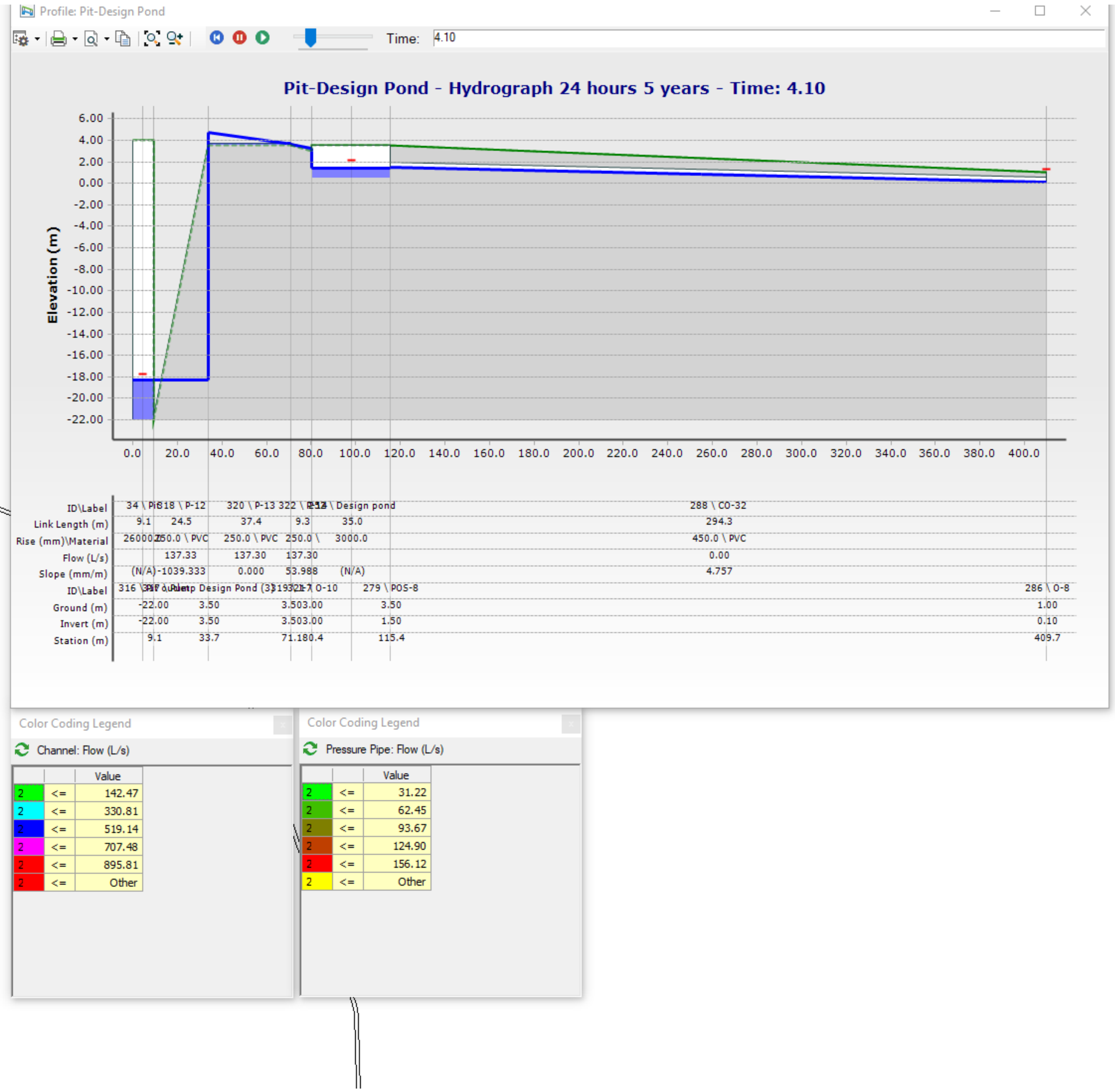




PROFILE AND LAYOUT. ROUTE: PIT - DESIGN POND - OUTFALL TO THE GULF OF BOTHNIA

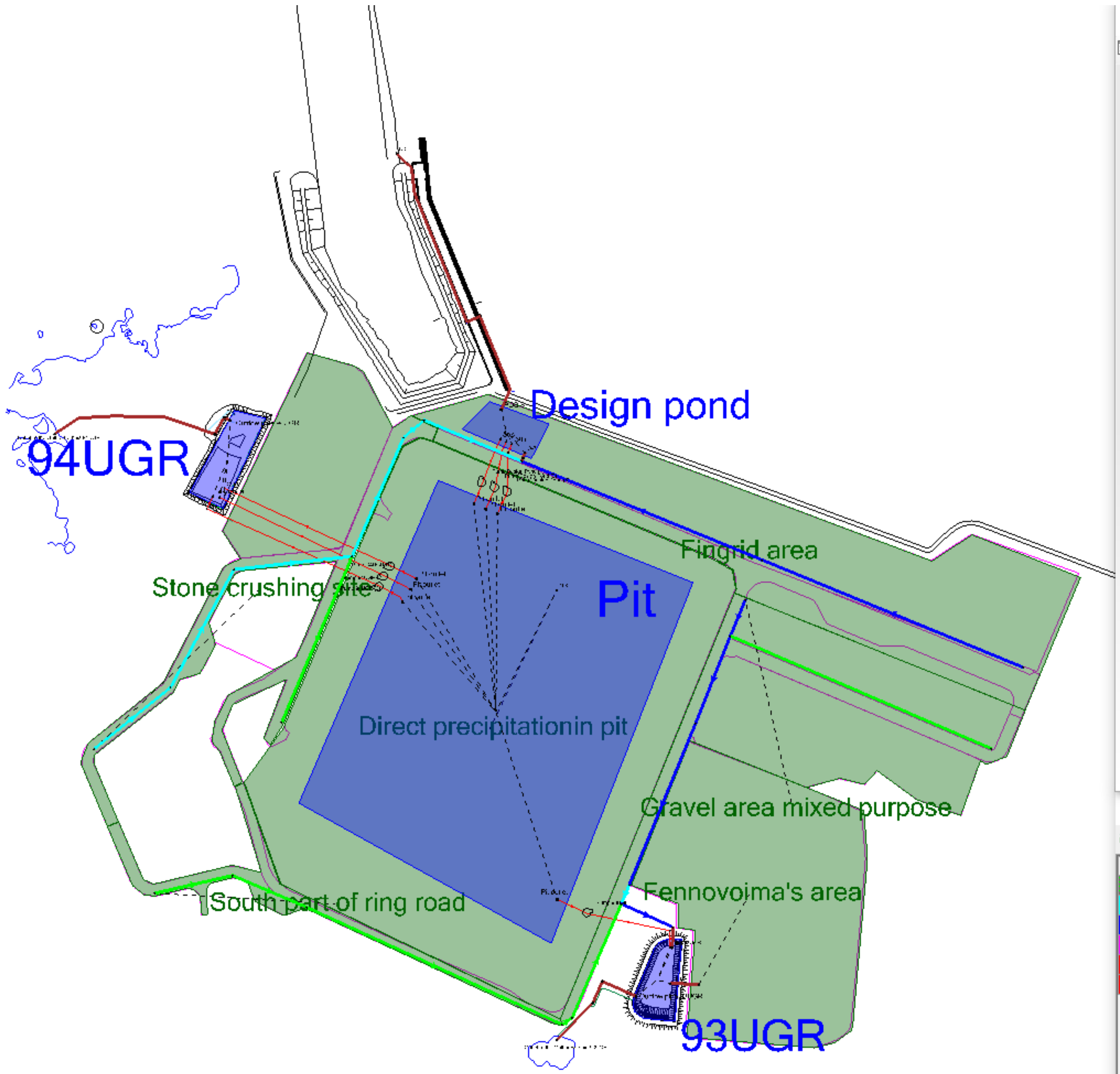
CALCULATION CASE: 5 YEARS RETURN PERIOD RAIN

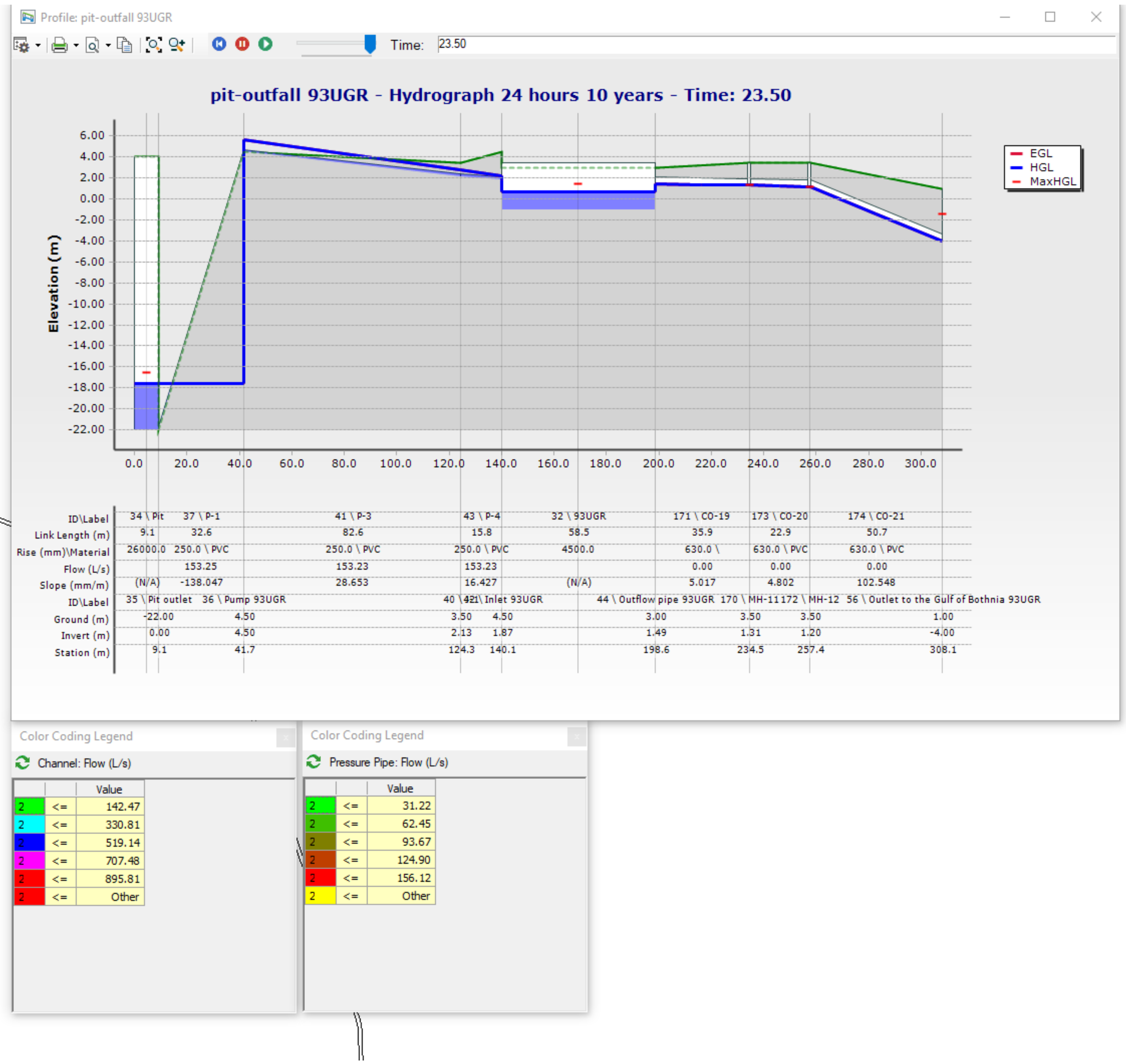




PROFILE AND LAYOUT. ROUTE: PIT - 93UGR - OUTFALL TO THE GULF OF BOTHNIA

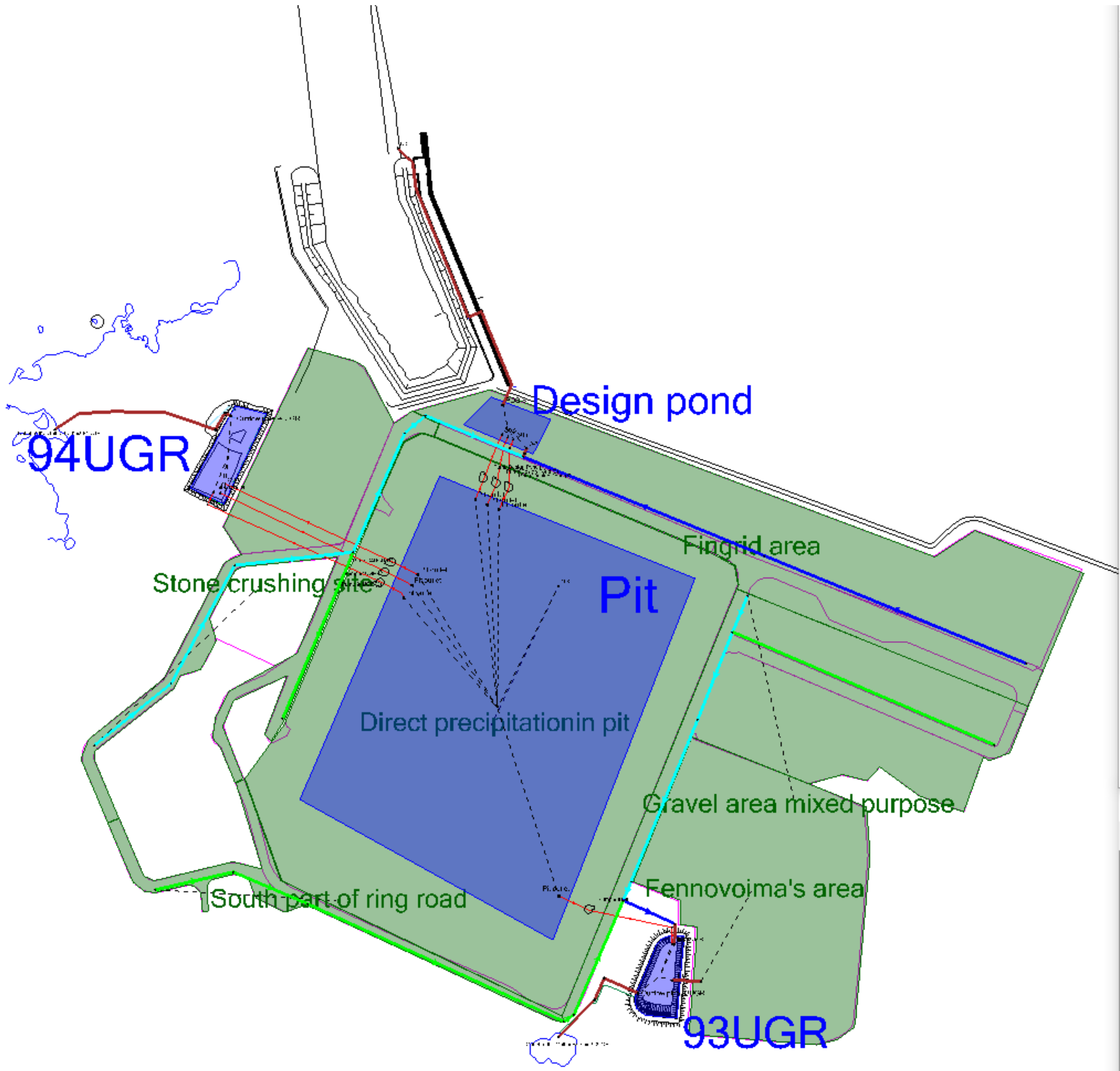
CALCULATION CASE: 10 YEARS RETURN PERIOD RAIN

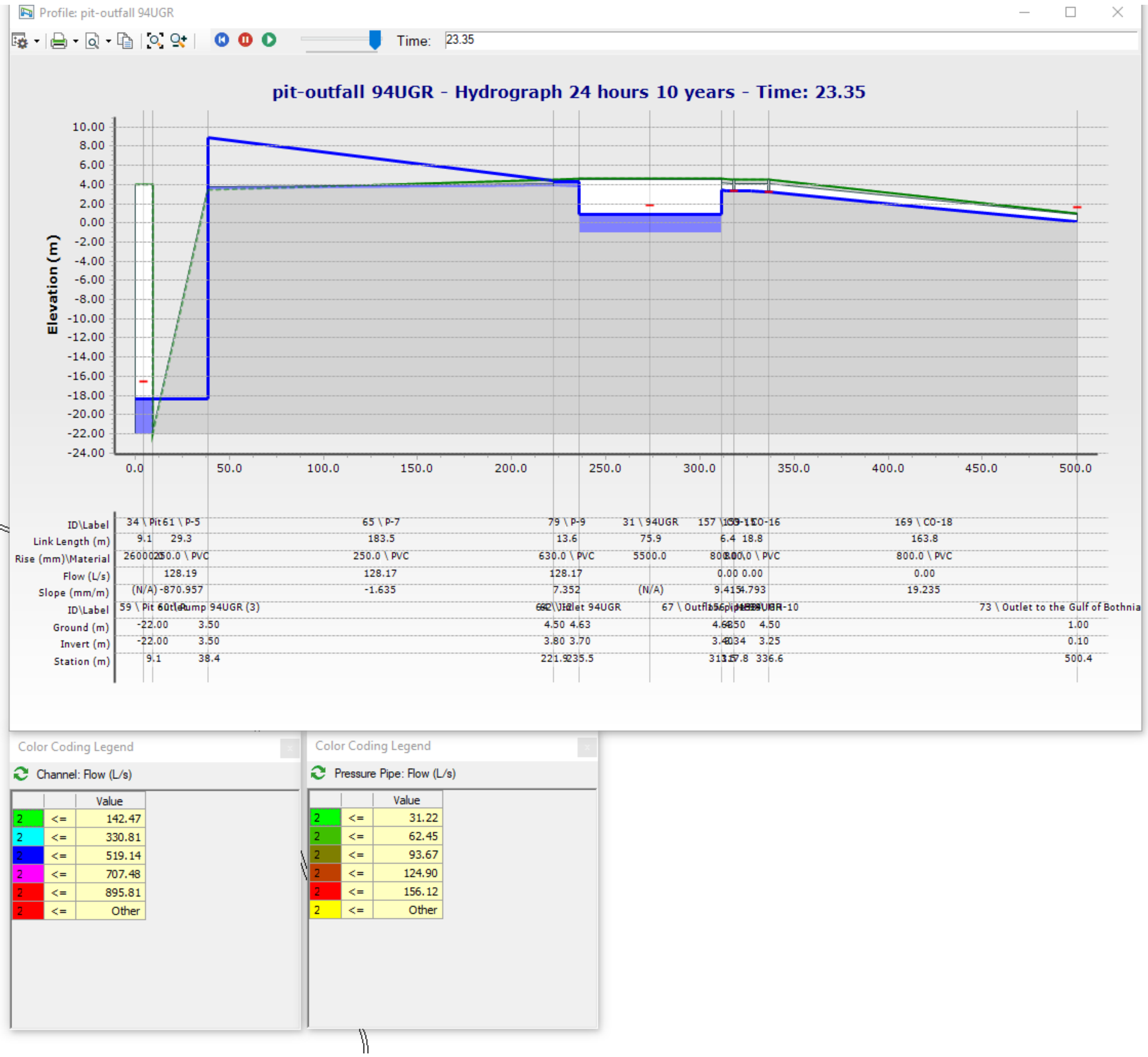




PROFILE AND LAYOUT. ROUTE: PIT-94UGR-OUTFALL TO THE GULF OF BOTHNIA

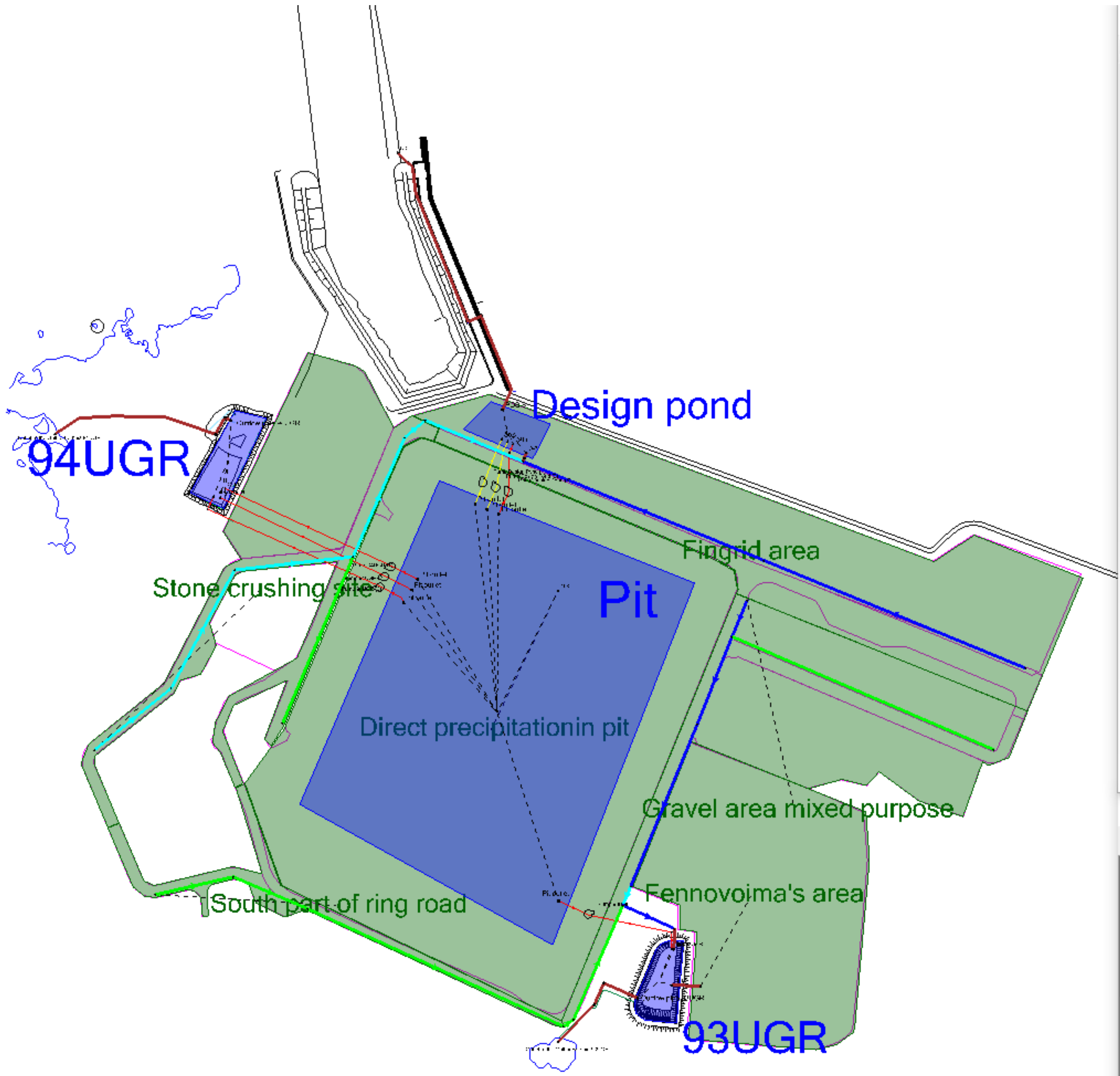
CALCULATION CASE: 10 YEARS RETURN PERIOD RAIN

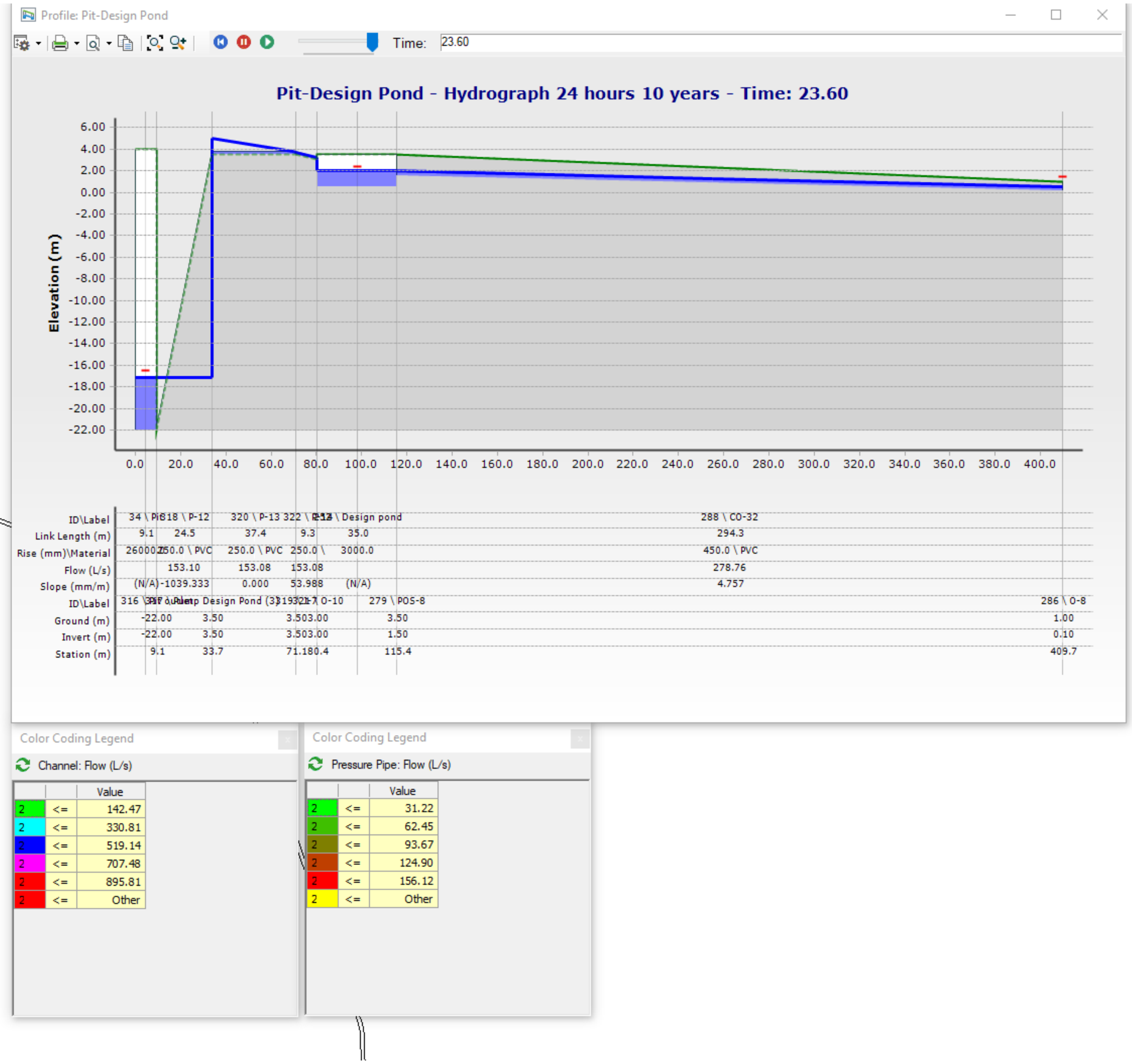




PROFILE AND LAYOUT. ROUTE: PIT - DESIGN POND - OUTFALL TO THE GULF OF BOTHNIA

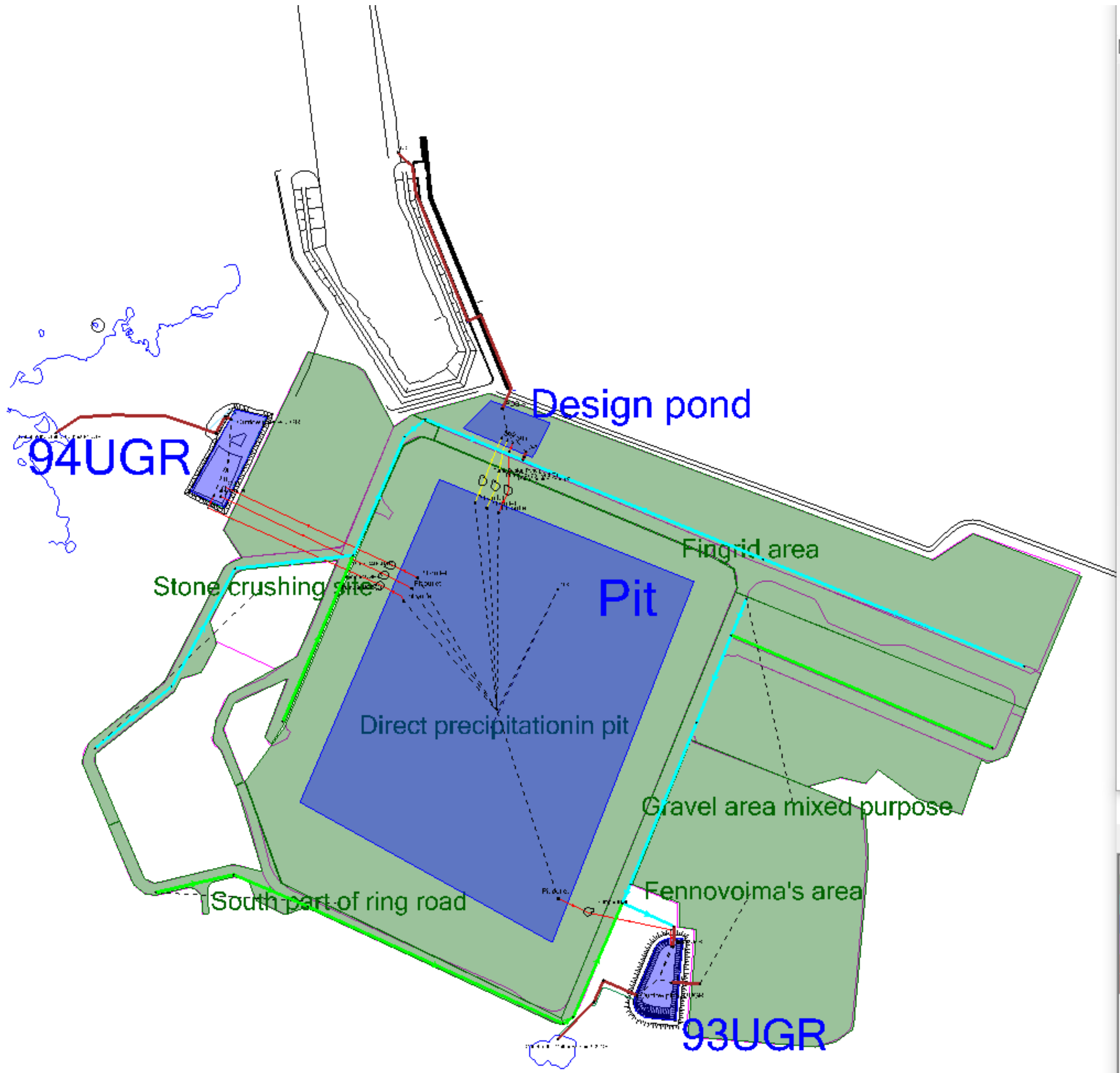
CALCULATION CASE: 10 YEARS RETURN PERIOD RAIN

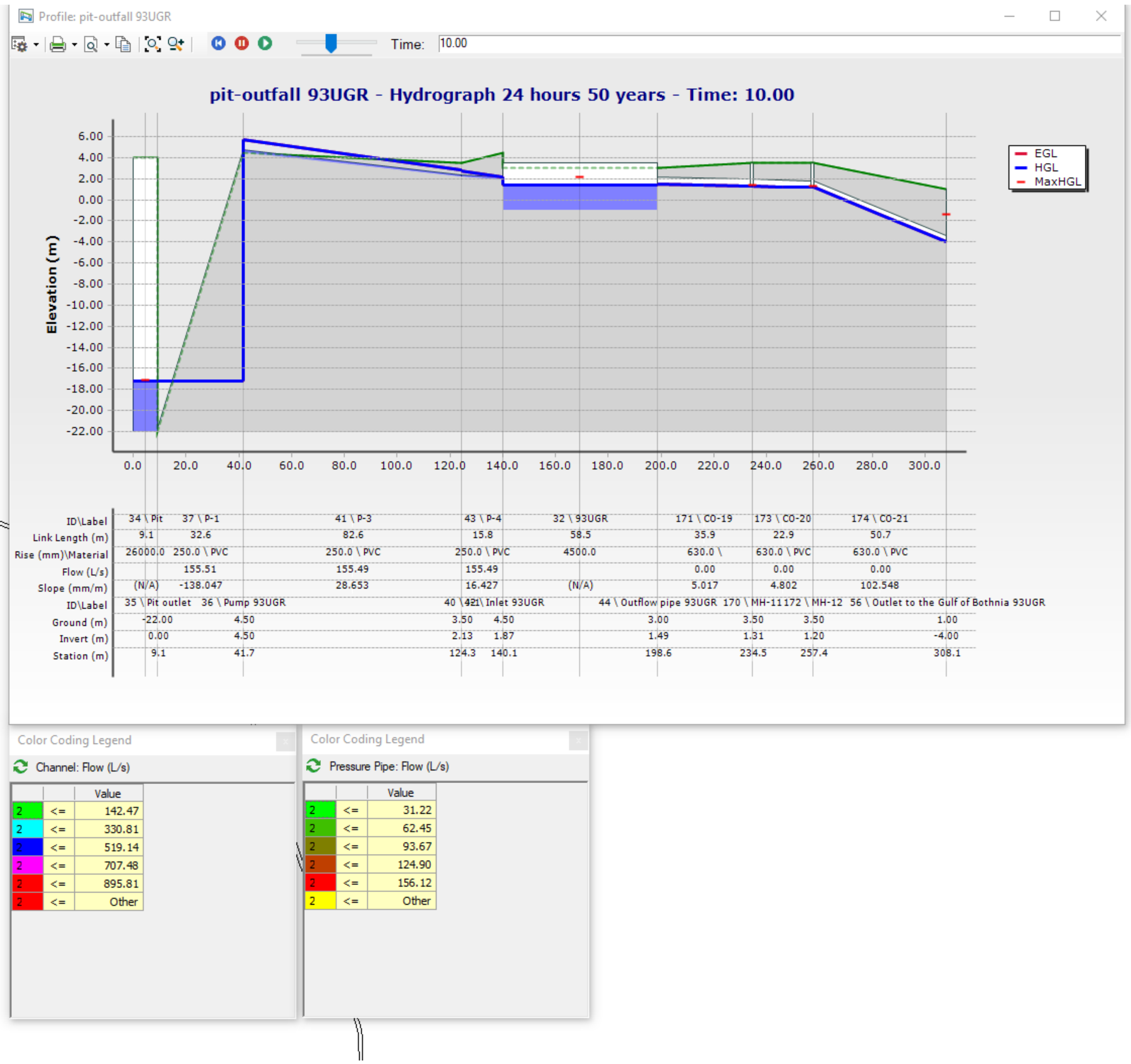




PROFILE AND LAYOUT. ROUTE: PIT - 93UGR - OUTFALL TO THE GULF OF BOTHNIA

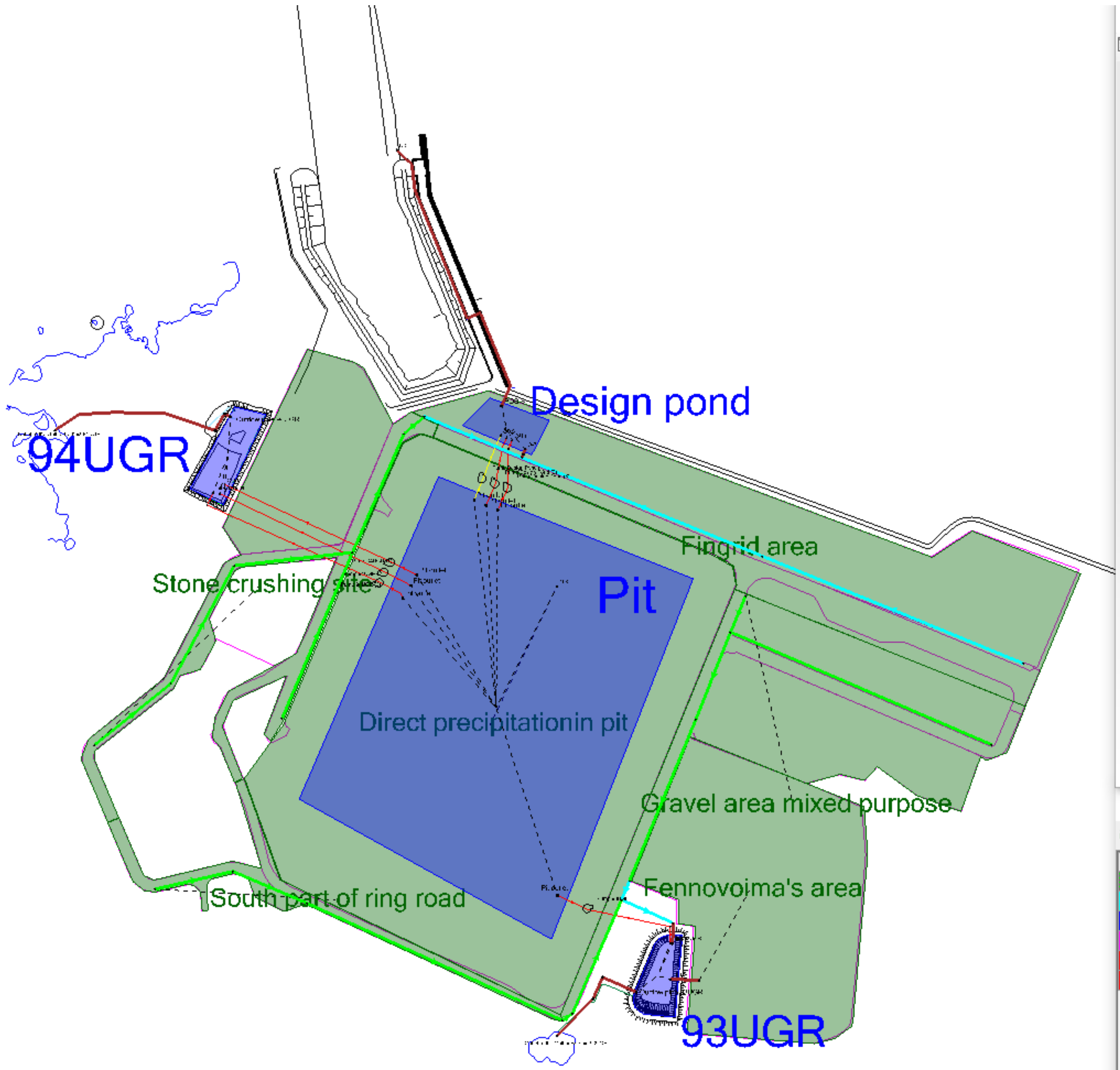
CALCULATION CASE: 50 YEARS RETURN PERIOD RAIN

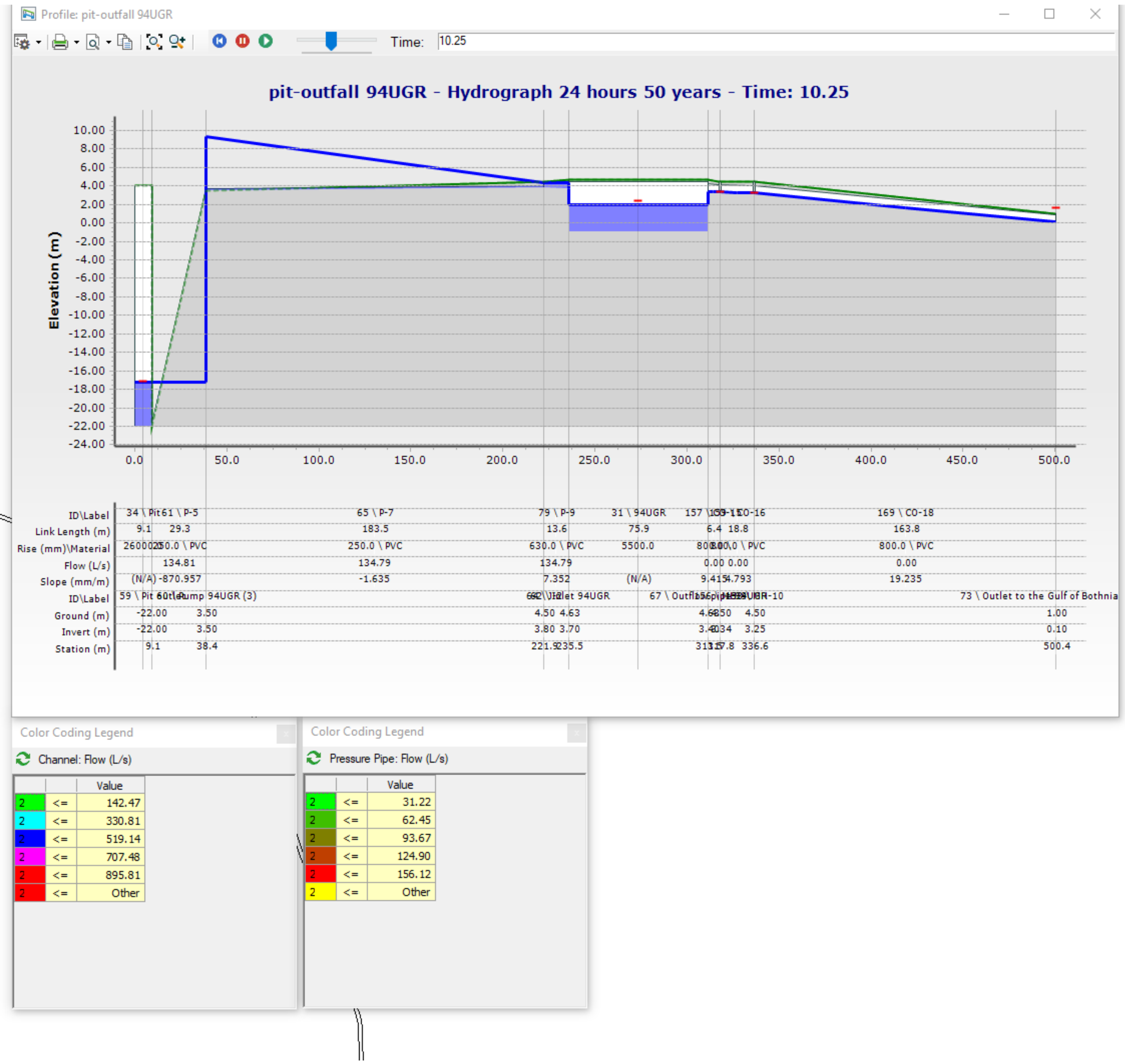




PROFILE AND LAYOUT. ROUTE: PIT - 94UGR - OUTFALL TO THE GULF OF BOTHNIA

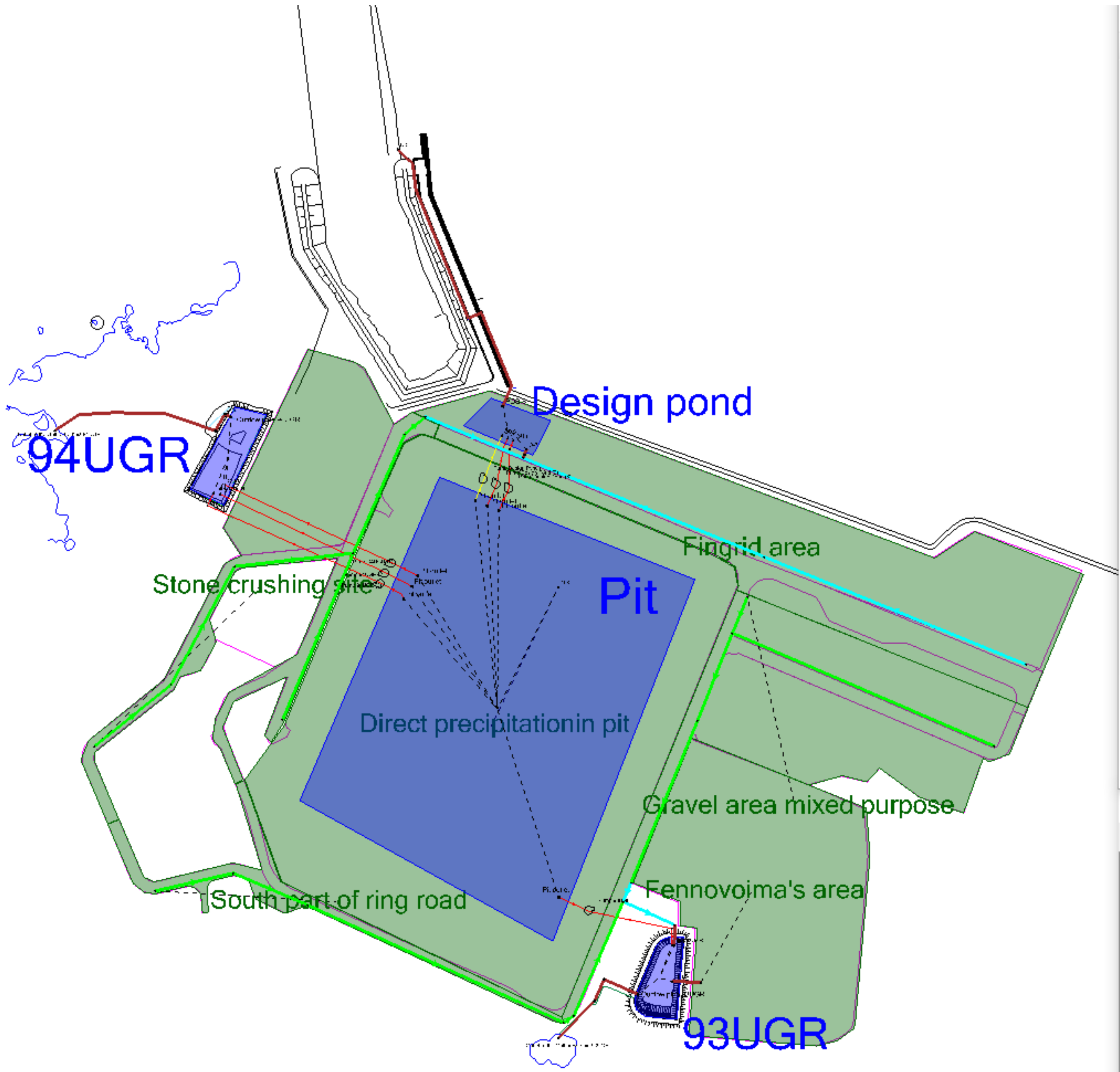
CALCULATION CASE: 50 YEARS RETURN PERIOD RAIN

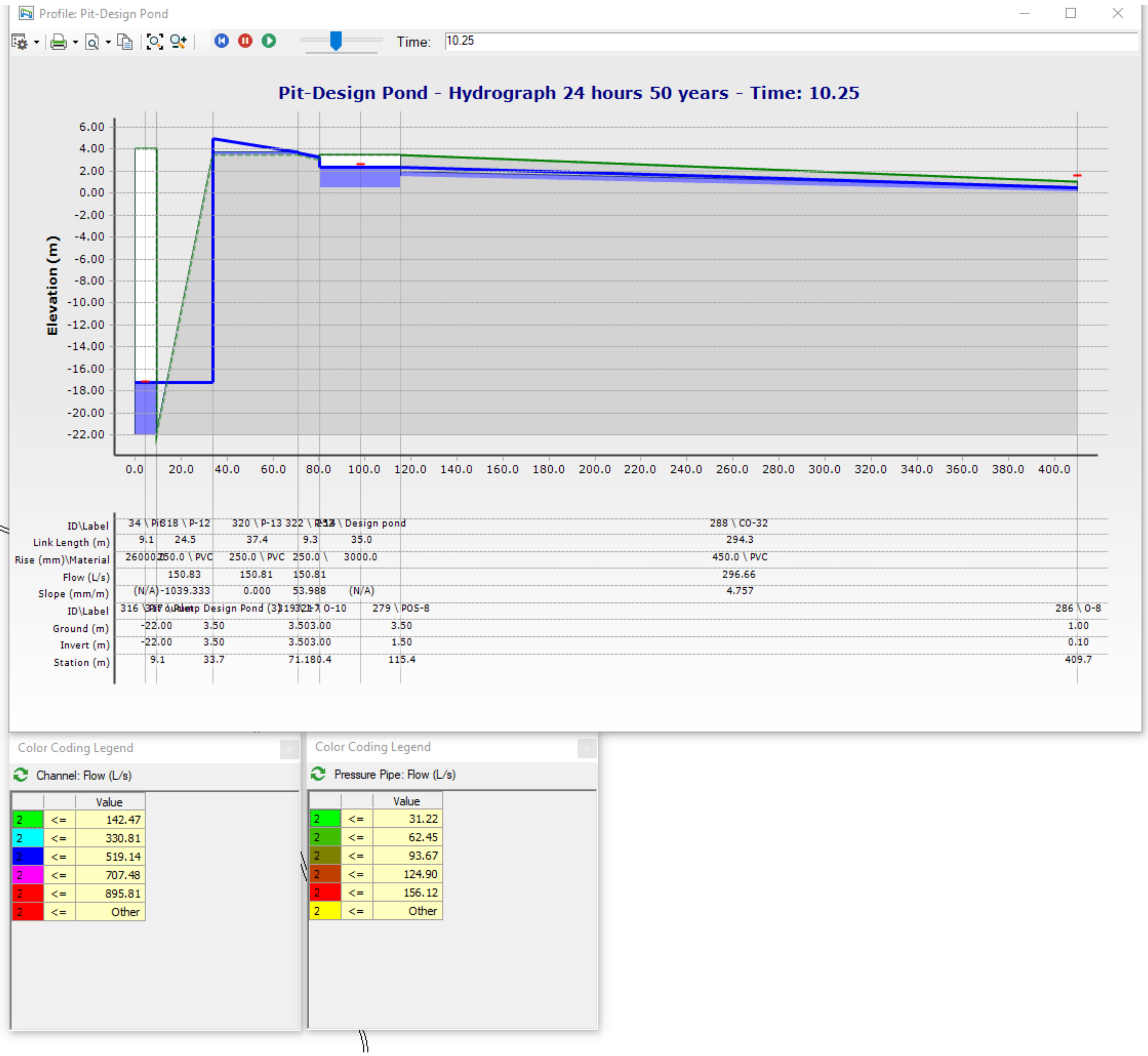




PROFILE AND LAYOUT. ROUTE: PIT – DESIGN POND - OUTFALL TO THE GULF OF BOTHNIA

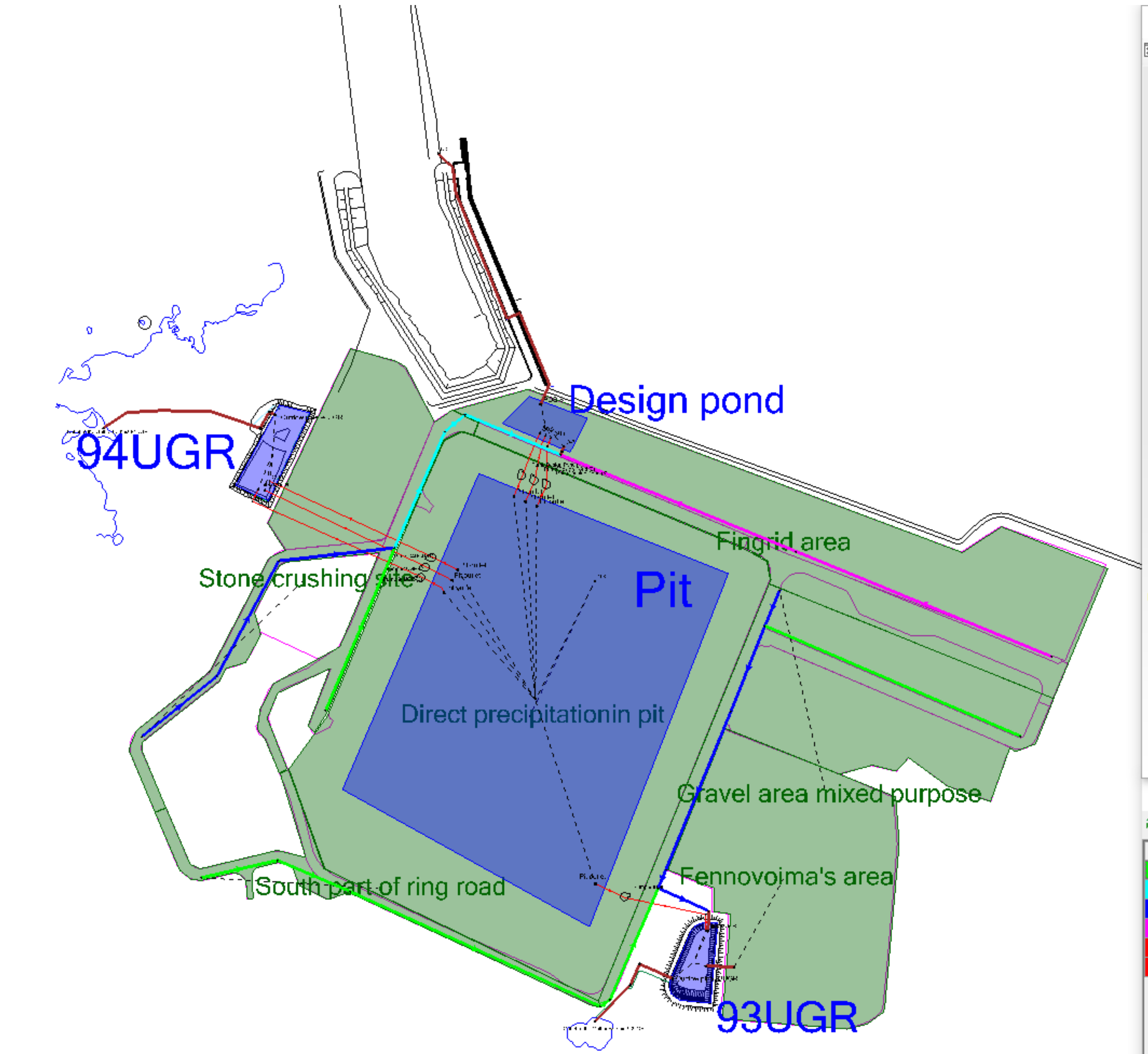
CALCULATION CASE: 50 YEARS RETURN PERIOD RAIN

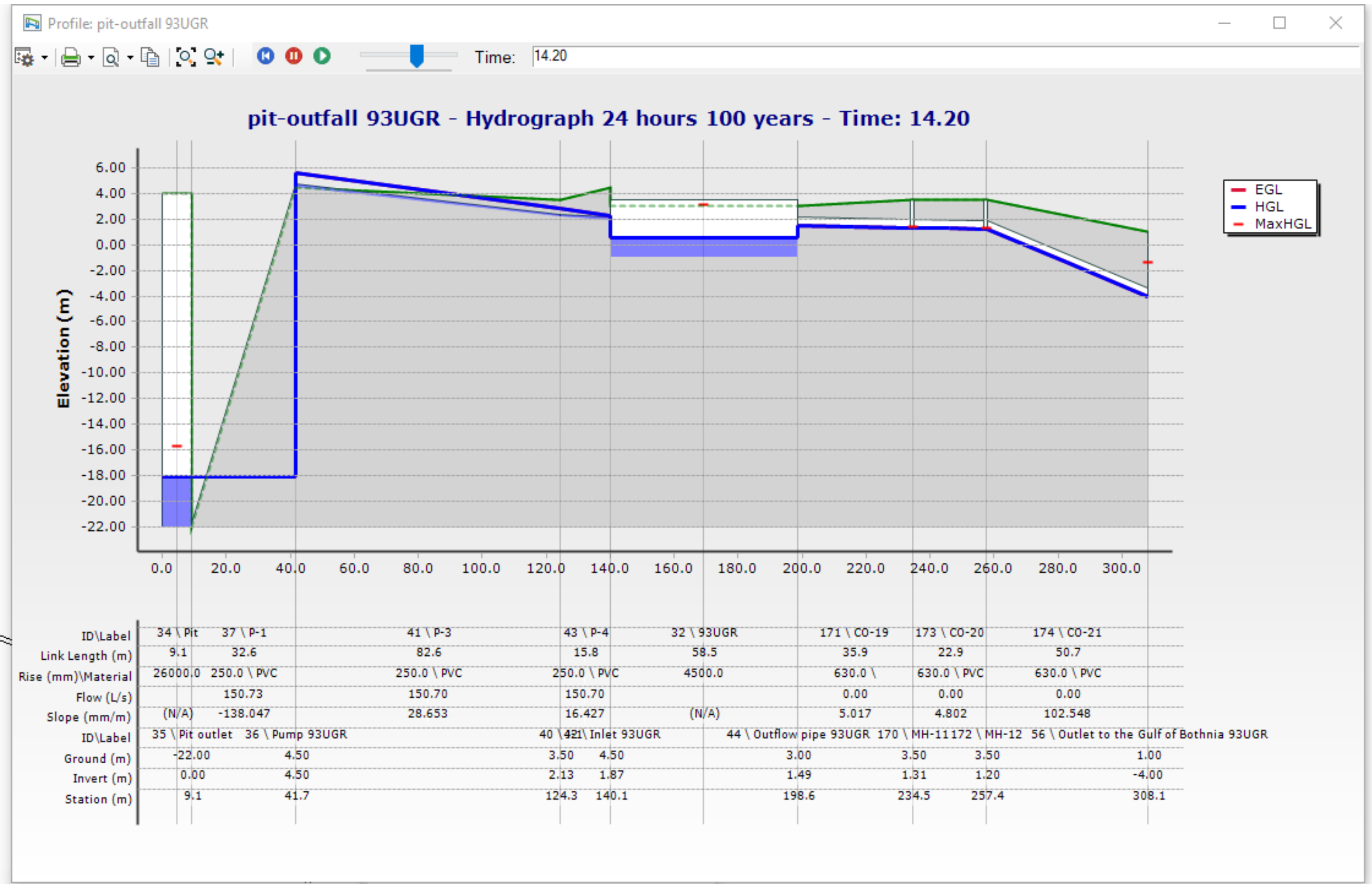


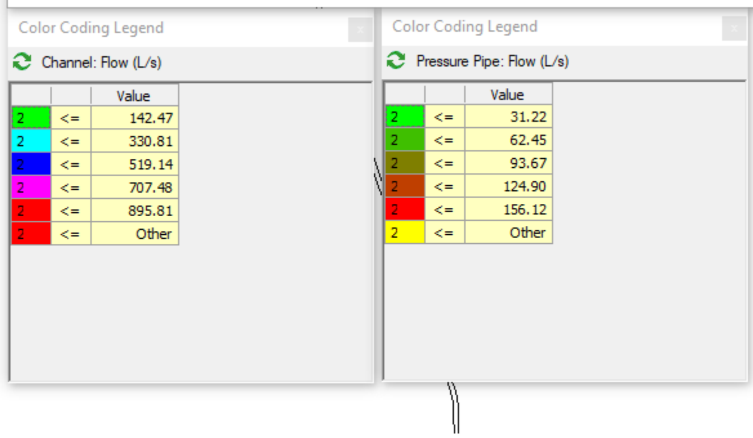


PROFILE AND LAYOUT. ROUTE: PIT - 93UGR - OUTFALL TO THE GULF OF BOTHNIA

CALCULATION CASE: 100 YEARS RETURN PERIOD RAIN

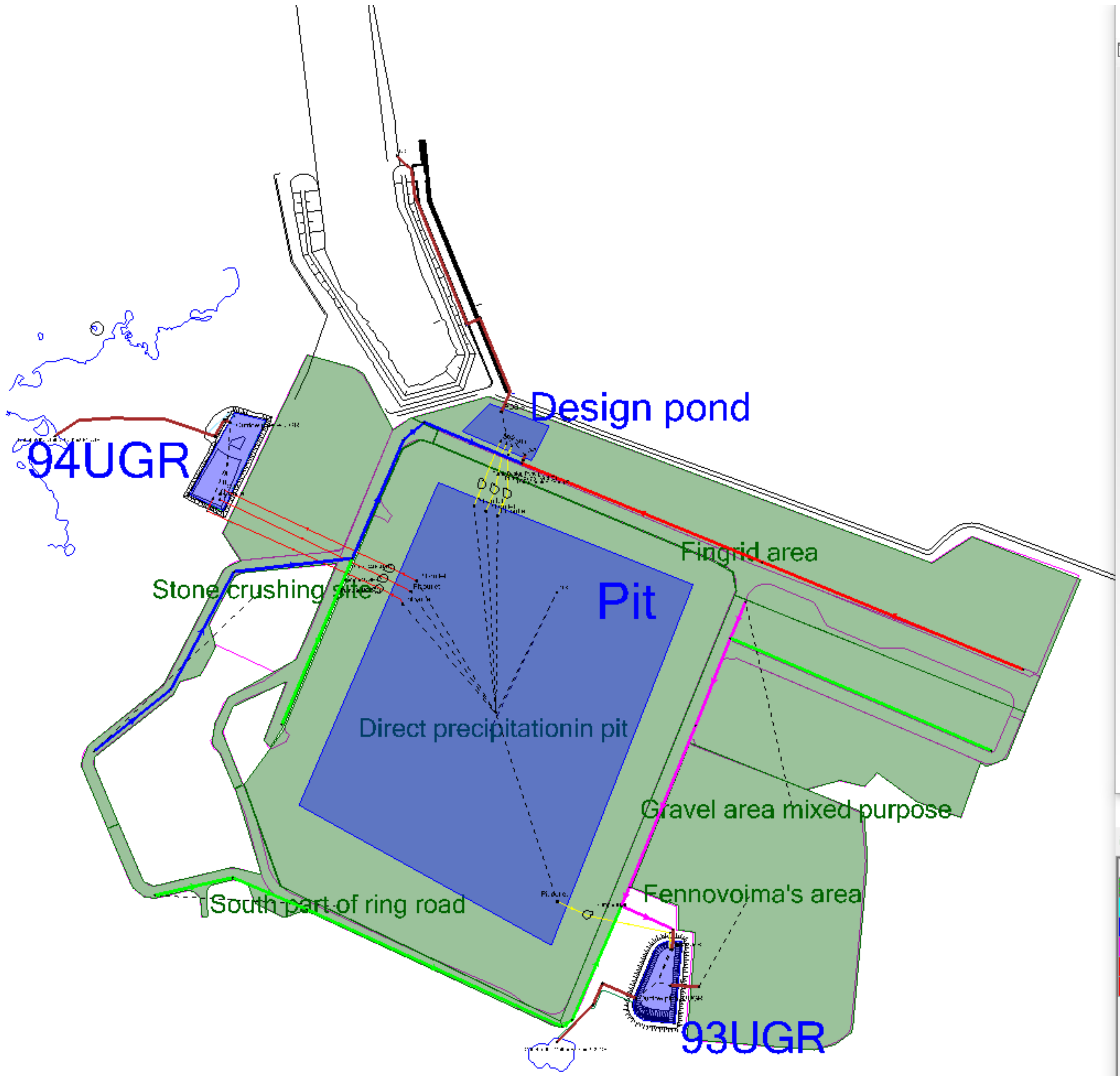


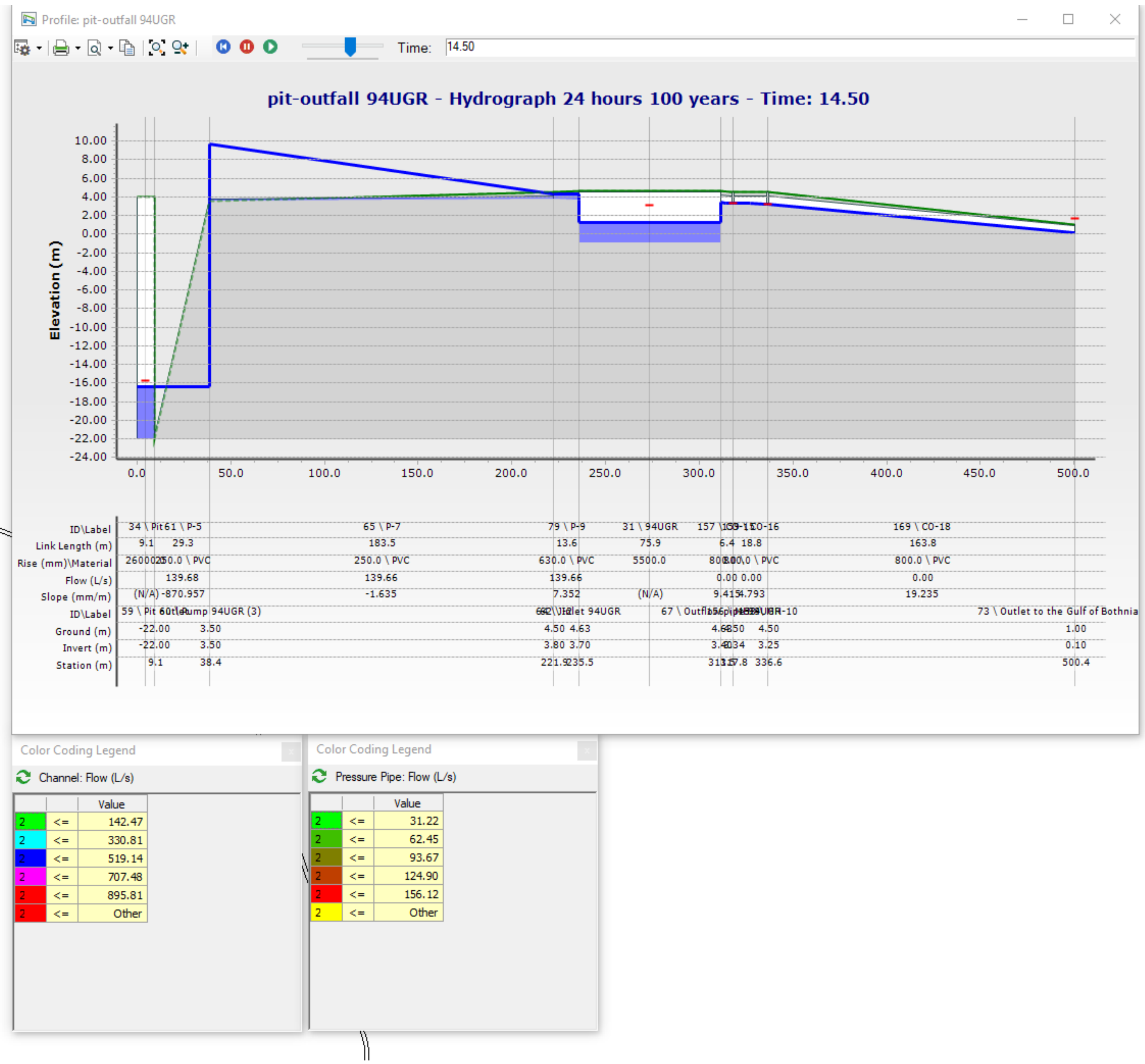




PROFILE AND LAYOUT. ROUTE: PIT - 94UGR - OUTFALL TO THE GULF OF BOTHNIA

CALCULATION CASE: 100 YEARS RETURN PERIOD RAIN





PROFILE AND LAYOUT. ROUTE: PIT - DESIGN POND - OUTFALL TO THE GULF OF BOTHNIA

CALCULATION CASE: 100 YEARS RETURN PERIOD RAIN