Vol. 5: Draft Environmental and Social Impact Assessment

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Prepared by SLR Consulting France SAS

Nenskra Hydropower Project

Supplementary Environmental & Social Studies

Volume 5
Hydrology & Water Quality Impact Assessment

Supplementary E&S Studies for the Nenskra HPP:

Volume 1 Non-Technical Summary	Volume 2 Project Definition	Volume 3 Social Impact Assessment	Volume 4 Biodiversity Impact Assessment	**Volume 5 Hydrology & Water quality Impact assessment**
Volume 6 Natural Hazards and Dam Safety	Volume 7 Stakeholder Engagement Plan	Volume 8 Environmental & Social Management Plan	Volume 9 Land Acquisition & Livelihood Restoration plan	Volume 10 Cumulative Impact Assessment

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1	21 February 2017	Authorized by JSCNH for public disclosure	N. Bukowski O. Cazaillet	D Buffin	Taek Won Seo

SLR Consulting France SAS
155-157 Cours Berriat - 38000 Grenoble France
T: +33 4 76 70 93 41
www.slrconsulting.com

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Acronyms

%	Percent
°C	Degrees Celsius
µg/l	Micrograms per litre
µS/cm	Micro-Siemens per centimetre
ADEME	*Agence de l'Environnement et de la Maitrise de l'Energie* (French agency for environment and energy management)
asl	Above sea level
C	Carbon
cm	Centimetre
CO_2-eq	Equivalent carbon dioxide
DO	Dissolved Oxygen
DSM	Digital Surface Model
E&S	Environmental & Social
EBRD	European Bank for Reconstruction and Development
EIA	Environmental Impact Assessment
EPC	Engineering-Procurement-Construction
ESAP	Environmental & Social Action Plan
ESIA	Environmental & Social Impact Assessment
ESMS	Environmental & Social Management System
EU	European Union
GHG	Greenhouse Gas
GIS	Gas Insulated Substation
Ha	Hectare
HEPP	Hydro Electric Power Plant
IFC	International Finance Cooperation
IPCC	Intergovernmental Panel on Climate Charge
J/kWh	Joules per kilowatt-hour
kg	Kilograms
km	Kilometre
km^2	Square kilometre
$l/s/km^2$	Litres per second per square kilometre
LALRP	Land Acquisition and Livelihood Restoration Plan
LUCF	Land-Use Change and Forestry
m	Metre
m asl	Metres above sea level
m^2	Square metre
m^3/s	Cubic metres per second
mg/l	Milligrams per litre
Mm^3	Million cubic meter
MoE	Ministry of Environment Protection and Natural Resources
MW	Megawatt
N	Nitrogen
NEA	National Environmental Agency

NTS	Non-Technical Summary
OECD	Organisation for Economic Co-operation and Development
OESA	Owners Environmental & Social Advisers
P	Phosphorus
PMF	Probable Maximum Flood
t	Tonnes
TBM	Tunnel Boring Machine
TJ	TeraJoule
TL	Transmission Line
TT	Transfer Tunnel
UNEP	United Nations Environmental Protection
US-EIA	United States Energy Information Administration
WEG	World Experience for Georgia
WRI	World Resources Institute

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Preamble

In August 2015, the final Environmental & Social Impact Assessment Report (ESIA) for the proposed Nenskra hydropower project (The Project) - located in the Svaneti Region - was submitted to the Government of Georgia as part of the national environmental permitting process. The 2015 ESIA report had been prepared by Gamma Consulting Limited (Gamma) – a Georgian environmental consulting company. The ESIA was based on the findings of field investigations undertaken in 2011 and 2014. Public consultations meetings had been held in May 2015 and the Environmental Permit was awarded by the Environmental Authorities in October 2015.

In the present document, the ESIA submitted in 2015 is referred as the 2015 ESIA.

Since then, several International Financial Institutions (the Lenders) have been approached to invest into the Project. In compliance with their environmental and social policies, the Lenders have recommended that a number of supplementary Environmental and Social (E&S) studies be undertaken to supplement the 2015 ESIA report.

This report is Vol. 5 of the Supplementary E&S Studies and has been prepared by SLR Consulting. It details the findings of the hydrology, geomorphology and water quality impact assessment. It is to be read in conjunction with the other volumes of the Supplementary E&S Studies which comprise the following:

- Volume 1: Non-Technical Summary
- Volume 2: Project Definition
- Volume 3: Social Impact Assessment
- Volume 4: Biodiversity Impact Assessment
- **Volume 5: Hydrology & Water Quality Impact Assessment** (**this document**)
- Volume 6: Natural Hazards and Dam Safety
- Volume 7: Stakeholder Engagement Plan
- Volume 8: Environmental & Social Management Plan
- Volume 9: Land Acquisition & Livelihood Restoration Plan
- Volume 10: Cumulative Impact Assessment

Summary

This report is the Hydrology and Water Quality Impact Assessment prepared in 2016 as part of the Supplementary Environmental and Social Studies for the proposed Project. The report contains the results of the field investigations conducted from August to November 2015 in the project-affected areas with respect to the hydrology, geomorphology and water quality of the Nenskra, Nakra and parts of the Enguri Rivers.

The hydrological and geomorphological assessment encompasses: (i) estimation of the characteristics of solid material transported by the Nenskra and Nakra Rivers; (ii) establishment of monthly river flow rates with and without the dam; (iii) assessment of the relative changes in solid material transport capacity of the Nenskra and Nakra River caused by the hydrological changes induced by the hydropower scheme – taking into account hourly variations in power turbine discharge flow rates, and (iv) identification of risks and recommended mitigation measures.

The water quality assessment encompasses: (i) establishment of baseline water quality in the Nenskra, Nakra and Enguri Rivers, (ii) prediction of water quality in the future Nenskra reservoir, Nenskra River downstream of the future dam and water quality in the Nakra River downstream of the future transfer tunnel diversion weir, (iii) estimation of project Greenhouse Gas (GHG) emissions, and (iv) identification of mitigation measures.

A. Field work

The baseline river water quality survey was undertaken during the period 28 September – 8 October, 2015 and comprised taking in-situ measurements of physical parameters and taking water samples for chemical analysis at 7 river stations (3 for the Nenskra, 2 for the Nakra and 2 in the Enguri).

The hydrological and geomorphological field work was undertaken concurrently with the water quality survey work, and comprised a drive/walk over the total length of the rivers in the study area to: (i) a visual appreciation of the characteristics of solid material transported into the rivers by tributaries; (ii) estimation of the characteristics of the solid material in the riverbeds, and (iii) interviews with local people and make a visual appreciation of zones where the rivers have been blocked in the past by solid material transported by tributaries and causing flooding both upstream – and downstream when the natural dam ruptured.

B. Assessment methodology

The baseline hydrology at a number of strategic locations along the Nenskra and Nakra Rivers has been established by the construction of a numerical model that takes into account sub-watershed areas, slopes, and run-off per hectare reported in literature for the Caucasus Mountains (Trans-Caucasian Hydro-Meteorological Research Institute, 1967). The model has been calibrated using the daily flow rates recorded at gauging stations in the study area. The model has then been used to predict hydrological conditions once the Project structure are in place by taking into account monthly discharges from the reservoir and powerhouse as defined by the Owners Engineer. Solid material transport capacity has been determined using recognized empirical formulae and the findings of the hydrological assessment.

The predicted water quality in the reservoir has been made using a quantitative approach comprising an estimation of the input of nutrient and inorganics into the reservoir water from the flooded biomass, soils and river inflow.

The quality of downstream water quality has been made using a quantitative approach and taking into account the predicted changes in hydrology, reservoir operation modes, reservoir water quality. Temperature impacts have been evaluated qualitatively taking into account baseline water temperature data, reservoir operation modes and dilution effects from tributaries.

C. Baseline water quality

There are no industrial activities and limited artisanal and agricultural activities upstream of the future reservoir on the Nenskra or the diversion weir on the Nakra Rivers. The waters have been found to be typical of pristine streams in granite and gneiss rock type areas. The concentrations of organic carbon and nitrogen are very low and phosphorous below detection limits. Nutrient input from river water into the future reservoir is consequently very low and this is an important factor that is taken into consideration in the calculations for determining the risk of creating eutrophic conditions.

D. Predicted impacts on hydrology

D.1 Between the dam and the powerhouse

The Nenskra River between the dam and the powerhouse is affected by a reduced flow as a result of the Project. Downstream from the dam, the Nenskra flow will comprise the sum of the ecological flow discharged from the reservoir and the natural runoff from the catchment area. The contribution from the natural runoff increases with the distance from the dam. Immediately upstream from the powerhouse - the average annual flow of the Nenskra will be reduced by 60 percent compared to the situation without the dam. The baseline annual average flow rate at this point is 26.5 m^3/s and with the dam this will be reduced to 9.9 m^3/s.

The reservoir will be at maximum operating level at the end of August and during the months of September, October and November. However, because of the important turbine capacity it is expected that for a “normal” year - in terms of precipitation and runoff - the reservoir water level can be managed without spillage of water via the spillway. Nevertheless, during a “wet“ year – when there is a higher than normal precipitation and which statistics indicate will occur 2 years out of every 10 - spillage of reservoir water via the spillway is expected to occur.

The spillage of reservoir water during a wet year is expected to occur principally during August, but could also occur in September. Spillage is expected to be in the range of 10 to 20 m^3/s, possibly for a duration of 2 to 4 hours each day, and possibly every day for about a month causing an increment increase in flow rate downstream.

D.2 Downstream from the powerhouse

The diversion of the Nakra water to the Nenskra reservoir results in an increase in the average annual river flow immediately downstream from the powerhouse. The average monthly increases range from 5 percent in summer to 300 percent in winter. The operating mode of the reservoir is driven by the need for the reservoir to be at full supply level at the end of November to allow power production during the period November to March when there is low reservoir inflow. Consequently during this period the stored reservoir water is released lowering the reservoir water level to the minimum level in March, and resulting an a flow rate downstream of the powerhouse that is significantly higher (300 percent) than that of the situation without the dam. During the period March to November reservoir inflow is high and the reservoir water level is increased and power production continued. During this period the increase in flow rate downstream for the powerhouse in small (5 percent) compared to natural conditions without the dam.

The downstream flow is also significantly influenced by the hourly variations in the discharge of the powerhouse turbines causing instantaneous Nenskra flows that are higher than those of the natural conditions. In February - when the river flow is at its lowest - the peak energy turbining would cause the river flow downstream of the powerhouse to vary from 3 to 50 m^3/s. In June – when the river is at its highest – the peak energy turbining would cause river flow to vary between 24 and 70 m^3/s. The 70 m^3/s peak flow rate is 14 percent higher than the maximum yearly average monthly natural flow conditions.

D.3 Downstream of the Nakra diversion weir

The diversion of the Nakra river waters via the transfer tunnel to the Nenskra reservoir will cause a reduction in the flow of the Nakra River downstream from the weir. The flow downstream from the weir will comprise the sum of the ecological flow and the natural runoff from the catchment area. Immediately downstream from the weir the reduction in average monthly flows range from 50 percent in February to 95 percent in June, and immediately upstream of the Enguri confluence the reduction varies from 30 to 60 percent.

D.4 Enguri River between the Nakra and Nenskra confluences

The reduced flow in the Nakra River will cause a slight reduction in the flow of the Enguri River between the Nakra confluence and the Nenskra confluence. The reduction in average monthly flows range from 6 percent in February to 11 percent in July.

D.5 Enguri River downstream from the Nenskra confluence and upstream from Enguri reservoir

The average annual flow of the Enguri River downstream from the confluence with the Nenskra will not be affected by the Nenskra Project. However, the average monthly flow rates will be modified by the storage in the Nenskra reservoir and release during the winter months. In February – when the river is naturally at its lowest, the Enguri flow will be increased by 73 percent. In July, when the river is naturally at its highest, the flow will be reduced by 9 percent.

D.6 Enguri Reservoir

The average annual flow into the Enguri reservoir will not be affected by the Nenskra Project. However the average monthly inflow rates will be modified by the storage in the Nenskra reservoir and release during the winter months. In February – when the inflow is naturally at its lowest, the reservoir inflow will be increased by 56 percent. In July, when the inflow is naturally at its highest, the inflow flow will be slightly reduced. However, this is not expected to cause a significant change to the functioning of the Enguri reservoir, and power generation potential in winter is expected to increase, which will be beneficial.

E. Predicted impacts on solid transport

The solid transport in the Nenskra River and the Nakra River will be affected by the changes in hydrology and changes in solid material transport capacity as shown in the Table overleaf.

In the Nakra valley, the Lekverari torrent and its confluence with the Nakra - immediately upstream of the Nakra village - is a zone which is vulnerable with respect to hydrological and geomorphological changes. In August 2011, a large landslide occurred in the Lekverari catchment and caused an important debris/mudflow to descend the Lekverari River and block the Nakra River. Within a few minutes flooding had occurred upstream and some 5 minutes later the Nakra River burst the blockage and caused a large wave of water to descend the river – but not causing flooding. The reduced flow in the Nakra River resulting from the diversion of the water to the Nenskra reservoir will reduce the capacity of the river to flush away accumulated sediments from any such similar mudflow events that could occur. However, the presence of the weir and diversion also reduces the peak discharge rate of the floods, and this is expected to affect the temporal aspects of any future mudflow related blockages that could occur. Consequently during flood events when the Nenskra reservoir is full – or the Nakra is blocked by a mud flow event – the Nakra diversion will be closed and the Nakra's natural flow reinstated. However, it should be noted that it is estimated that the time-scales for upstream flooding then rupture to occur for a mudflow blockage and flood event of similar magnitude to that of 2011 could be longer. For the case where there is no overtopping of the blockage, the rupture of the blockage is related to the hydraulic load and not the flow rate of the river. However, if overtopping occurs the external erosion caused by the flow of water will cause the blockage to be eroded away.

A similar, but less serious situation also exists at the confluence of the Laknashura and Nakra, further upstream.

Reach	Length (km)	Flow cf. baseline situation	Solid transport capacity for material > 1 cm in diameter (cf. baseline) / largest material moved compared (cf. baseline)
Nenskra River			
Dam to discharge of ecological flow	0.7	1.5%	Nil- risk of accumulation of solid material
Ecological flow discharge – confluence with Okrili tributary	2.3	5% – 15%	Significant reduction in capacity
Okrili tributary – powerhouse	13	15% – 40%	45 - 50% 10 cm cf. 16 cm
Powerhouse – confluence with Enguri	3	125% – 134%	160% in May, August 75% in July No change June and August
Nakra River			
Diversion weir – confluence with Lekverari tributary	3.6	14% - 25%	15% 4 cm cf. 14 cm
Lekverari confluence – Enguri Confluence	5	25% - 40%	30 - 40% 7 cm cf. 14 cm
Enguri			
Nakra confluence – Nenskra confluence	18	93%	No discernible change
Nenskra confluence – Enguri reservoir	10	100%	No discernible change

The solid transport capacity of the Nenskra River will be reduced as shown in the Table above. However, this will be balanced by the fact that the dam will trap much of the sediment transported from the upper Nenskra catchment area and because the tributaries downstream of the dam do not transport significant amounts of solid material. Consequently no significant geomorphological impacts are expected along the Nenskra River.

The increase in flow of the Nenskra downstream from the powerhouse is not expected to cause erosion of the riverbed. This is because the baseline conditions of the riverbed along this reach appear to be "armoured", i.e. the smaller solid material from the riverbed have already been flushed away leaving only the larger cobbles and boulders which are not susceptible to erosion from an increased flow rate. However, there is a possibility that bank erosion may occur in the 2 kilometres downstream from the powerhouse. Consequently monitoring is recommended and if bank erosion observed then the banks are to be reinforced using suitable means.

F. Predicted impacts on water quality

F.1 Predicted reservoir water quality

The reservoir water quality is expected to be modified for the first 2 - 3 years after reservoir filling. Predicted Phosphorus concentration in the reservoir – which is an indicator of the potential for eutrophic conditions - is expected to be at levels typical of eutrophic reservoirs during the first 2 to 3 years, and subsequently decreasing to concentrations typical of mesotropic reservoirs. Dissolved Oxygen concentration is expected to be in the order of 1-2 milligrams per litre (mg/l) in the first year and in the order of 5 mg/l in the second or third year. However because of reservoir temperature and high throughput, development of excessive primary production causing algal blooms, pH changes, creation of anoxic conditions and further water quality degrading are not expected.

The reservoir water quality is greatly influenced by the mode of reservoir operation: (i) there is a very high rate of recharge – equivalent of 4.64 times the reservoir volume per year, and (ii) the reservoir is almost completely empty at the end of March – with only 10 percent of the volume remaining. The nutrients that are released from flooded biomass and soils into the reservoir water - and causing modified water quality - will be flushed out of the reservoir each year. However, the amount of nutrient released from the biomass and soils into the reservoir water will decrease each year. Consequently reservoir water quality will improve over time and after the third or fourth year after reservoir filling the reservoir water is expected to be in the range found in mesotropic reservoirs.

The reservoir operation is such that each year it is filled during the period April to November. During this period the inflow comprises essentially glacial melt water. However it can be expected that the reservoir surface water will be warmed during this period. Nevertheless, it is considered unlikely that a thermocline will form because of the high water throughput, the shape of the reservoir and the operating modes. A temperature gradient will probably form with surface temperatures in the order of 15 degrees Celsius and bottom water in the order of 5 – 8 degrees Celsius.

F.2 Predicted water quality in the Nenskra downstream from the dam

In the first 2 to 3 years after reservoir filling, the water quality in the Nenskra between the dam and the powerhouse is influenced by the modified water quality of the ecological flow from the reservoir. Although the ecological flow is rapidly diluted by the inflow from tributaries, there could be a discernible increase in the concentrations of nutrient between the dam and Okrili confluence in the first 2 to 3 years after reservoir filling. The amount of nutrients discharged from the reservoir will decrease over time and after 3 years the quality of river water is expected to be similar to natural conditions. During the first 3 years after reservoir filling the stretch from the dam to Tita will be affected by low Dissolved Oxygen (in the range of during 4 to 8 mg/l). Further downstream the Dissolved Oxygen will have increased due to re-oxygenation and dilution. In terms of temperature, during the period December to February, the ecological flow is expected to be at a temperature that is slightly higher - by 2 to 3 degrees Celsius - than natural conditions, but the river water temperature will rapidly decrease due to cold air temperature and dilution from tributaries. At Tita, the river temperature is expected to be the same as those of natural conditions.

During wet years (2 years out of 10) it is expected that there will be spillage of reservoir water via the spillway and which discharges into the Nenskra River. It is estimated that the flow will be in the order of up to 20 m^3/s (compared to an ecological flow of 0.85 m^3/s) and could be discharged for a few hours every day for a duration in the order of 1 month. In the first 3 years after reservoir filling, this water will be modified. It will also be warmer (possibly in the order of about 15 degrees Celsius compared to natural conditions in the order of 10 degrees Celsius).

When this spillage occurs, the dilution effect from tributaries is minimized and the Nenskra water quality will be very similar to that of the reservoir water, which in the first 3 years is modified with high concentrations of nutrient and organic carbon and low Dissolved Oxygen.

In the reach of the Nenskra River downstream from the powerhouse, there is an important contribution to the flow from the turbined water from the reservoir. Consequently the quality of the water is heavily influenced by the reservoir water quality – and modified during the first 3 years of operation after reservoir filling.

F.3 Predicted water quality in the Nakra River

No impacts on water quality in the Nakra are expected. The reduced flow is not expected to have an effect on water quality or temperature. The presence of the diversion weir and the upstream pool is not expected to cause a discernible change in water quality or temperature.

G. Climate change, GHG emissions and micro-climate change

The Project will monitor a range of climatic parameters to identify climate change trends in the catchment. Analysis of the monitoring results will inform any modifications to the operation of the Project as may be required. The only potential risk identified for the project requiring to be accounted for in the design of the dam and resulting from climate change is that of a possible increase in extreme rainfall and flooding events as could potentially influence the PMF value. Consequently, JSCNH will undertake a dedicated climate change risk assessment in alignment with best international practices to model and verify the PMF value that the spillway will be designed to evacuate safely.

Reservoir Greenhouse Gas (GHG) emissions and construction GHG emissions have been calculated. Reservoir GHG emission calculations are based on an estimate of the amount of flooded biomass and assumes that carbon in the biomass is conversed to carbon dioxide in an aerobic biodegradation process. Construction GHG emissions have been estimated by considering the amounts of mineral material and concrete required for dam construction. Construction GHG emissions represent 2.3 million tons of CO_2-eq over 4 years. Reservoir emissions represent 51 thousand tonnes – produced in the first 7 years after reservoir filling. The reservoir emissions have been compared to benchmark indicators (reported by the World Commission on Dams) and the value of 643 g CO_2-eq/ m^2/year is comparable with that of dam-reservoirs in Canada and Finland. The combined construction and reservoir emissions (averaged over 34 years) represent an average of 32 grams CO_2 per kWh which compares favourably with typical values reported by the Intergovernmental Panel on Climate Change (IPCC, 2011).

In terms of micro-climate change, it is possible that there may be localized micro-climate change in the vicinity of the dam-reservoir - but not extending down the valley further than Tita - with slightly lower temperatures in summer and slightly higher humidity in the summer. No detectable changes are expected in the winter months. However, it is more likely that the micro-climate changes are negligible compared to regional climate changes as a result of global warming.

H. Mitigation measures

The key mitigation measures with regard to hydrology are as follows:

- Hydraulic structures are designed to ensure the continuous release of ecological flows into the rivers downstream from the hydraulic structures. The design of the structures includes features to enable the ecological flow to be increased if necessary once the Project is in operation.

- Flood control measures will be implemented to ensure that flood flow rates during the scheme's operation during normal and flood conditions to be no higher than the case without the presence of the dam structure. This is achieved through reservoir operation rules and the installation of a remotely operated gate at the inlet to the Nakra transfer tunnel, so that the Nakra diversion can be stopped when the Nenskra reservoir is at full supply level and spilling.

The key mitigation measure with regard to geomorphology concerns sediment accumulation in the Nakra. The Nakra diversion weir and transfer tunnel are designed and will be operated to ensure that the sediment transport function of the Nakra River is maintained. The weir is equipped with two large gates to allow sediment that is trapped in the head pond to be flushed downstream. Periodically the gate on the Nakra transfer tunnel inlet will be closed and simultaneously the weir gates opened to allow the Nakra River's natural flow rate to be re-established so that sediment that has accumulated in the riverbed can be flushed away. This action will be taken in the event of a mudflow/debris flow events blocking the Nakra flow.

The key mitigation measures that are planned for water quality are as follows:

- Management of cleared vegetation is to include solutions for preventing the burning vegetation. Tree trunks of economic value are to be monetized. Tree trunks and branches of no (or little economic) value will not to be burnt – solutions for use as firewood in other areas of Georgia are to be identified (e.g. use as fuel in thermal plants - such as cement works). Solutions for allowing natural biodegrading of soft biomass to avoid burning are to be identified.
- The potential risk of acid rock drainage caused by tunnel boring spoil containing sulphur bearing rock cannot be excluded. Any such excavated sulphur bearing rock when exposed to atmospheric conditions may results in acid drainage. This risk will be investigated by a team of geologists through screening of spoils as they are excavated. Plans will be prepared for testing excavated rock and means to manage the spoil to prevent any acid drainage being discharged to the natural environment.

1 Introduction

1.1 Overview

This report is the Hydrology and Water Quality Impact Assessment prepared as part of the Supplementary Environmental and Social studies for the Nenskra HPP Project (the Project). The investigations conducted from August to November 2015 in the project-affected area cover the hydrology, geomorphology and water quality of both the Nenskra and the Nakra rivers.

The proposed Nenskra Hydropower Project is a greenfield high head hydropower project with an installed capacity of 280 MW, located in the upper reaches of the Nenskra and Nakra valleys in the North Western part of Georgia in the Samegrelo-Zemo Svaneti Region (see Map 1-1).

The Project uses the available discharges from the Nenskra River and the adjacent Nakra River, developing a maximum available head of 725 metres down to the powerhouse located approx. 17 kilometres downstream the dam.

The main project components comprise a 130 metre high, 870 metre long asphalt face rock fill dam on the upper Nenskra River creating a live storage of about 176 million cubic metres and a reservoir area at full supply level of 267 hectares. The Nakra River will be diverted into the Nenskra reservoir through a 12.25 kilometre long transfer tunnel. The power waterway comprises a headrace tunnel of 15.1 kilometre, a pressure shaft and a 1.79 kilometre long underground penstock. The above ground powerhouse is located on the left bank of the Nenskra River and will house three vertical Pelton turbines of 93 MW capacity each, for a total installed capacity of 280 MW. A 220 kV transmission line that connects the powerhouse switchyard to a new Khudoni Substation will have to be built.

The main construction period is planned to start in Q4 2017 and will last 4 years. Some early works have been executed starting in October 2015 and are ongoing: upgrading of access roads and geotechnical studies. Power generation is planned to start end of 2020 if the conditions are favourable.

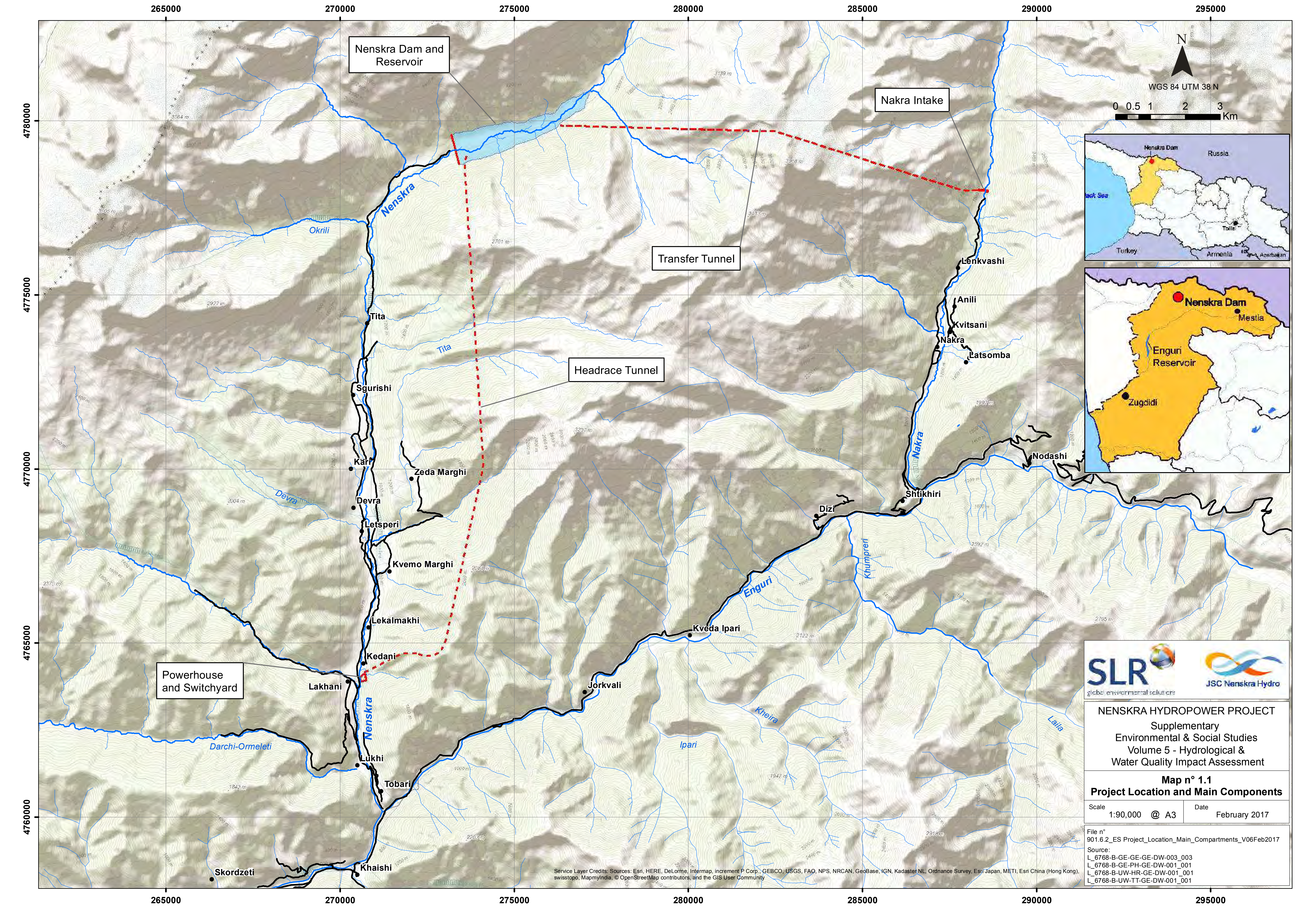
The Project is being developed by JSC Nenskra Hydro (JSCNH), whose main shareholders are K-water, a Korean government agency and Partnership Fund, an investment fund owned by the Government of Georgia. K-water and Partnership Fund are referred to as the Owners in this document.

1.2 Objectives

1.2.1 Hydrology and geomorphology assessment

The objectives of the downstream hydrology assessment are:

- Define the reservoir operating rules so that they can effectively be taken into account in the hydrology impact assessment;
- Analysis of the baseline data (see section 1.3.1) so that the effects of the physical presence of the dam and reservoir operation on the downstream hydrology, sediment transport and geomorphology in the Nenskra and Nakra Rivers can be predicted at strategic location;



Nenskra Dam and Reservoir
Nakra Intake
Transfer Tunnel
Headrace Tunnel
Powerhouse and Switchyard
WGS 84 UTM 38 N
0 0.5 1 2 3 Km
Nenskra
Okrili
Tita
Devra
Darchi-Ormeleti
Nakra
Enguri
Khumpreri
Kheira
Ipari
Laila
Tita
Sgurishi
Kari
Zeda Marghi
Devra
Letsperi
Kvemo Marghi
Lekalmakhi
Kedani
Lakhani
Lukhi
Tobari
Khaishi
Skordzeti
Jorkvali
Kveda Ipari
Dizi
Shtikhiri
Nodashi
Lenkvashi
Anili
Kvitsani
Nakra
Latsomba
Russia
Turkey
Armenia
Azerbaijan
Tbilisi
Nenskra Dam
Mestia
Enguri Reservoir
Zugdidi
265000 270000 275000 280000 285000 290000 295000
4780000 4775000 4770000 4765000 4760000
SLR global environmental solutions
JSC Nenskra Hydro
NENSKRA HYDROPOWER PROJECT
Supplementary Environmental & Social Studies
Volume 5 - Hydrological & Water Quality Impact Assessment
Map n° 1.1
Project Location and Main Components
Scale 1:90,000 @ A3
Date February 2017
File n° 901.6.2_ES Project_Location_Main_Compartments_V06Feb2017
Source:
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L_6768-B-GE-PH-GE-DW-001_001
L_6768-B-UW-HR-GE-DW-001_001
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- Predict the order of magnitude of modified flow regimes of the Nenskra and Nakra Rivers on the Enguri River water flow and sediment transport and on the Enguri reservoir water levels and sediment inflow;
- Assess the risk of future blockage in the Nakra River and the Nenskra River caused by the accumulation of rocks entrained from the slopes downstream the dam and the diversion weir - and reduced bed load capacity/ water flow rate. Provide a qualitative assessment of the flooding risks/implications resulting from potential blockages of the Nakra and Nenskra Rivers, and
- Identification of mitigation measures related to impacts on hydrology and which are carried forward to Vol. 8 ESMP.

1.2.2 Water quality assessment

The objectives of the water quality assessment are:

- Undertake a water quality survey to document the water quality characteristics of the two project-affected rivers;
- Conduct an assessment of the project induced impacts on water quality based on the predicted changes in reservoir water quality during the first years following impoundment and during operation of the hydropower scheme;
- Define a water quality impact mitigation strategy including the structural and non-structural measures and operational water quality management measures.
- Identification of mitigation measures related to impacts on water quality and which are carried forward to Vol. 8 ESMP.

1.3 Methodology

1.3.1 Hydrology assessment

The study has computed monthly river flow rates and water depths at strategic locations along the Nenskra and Nakra rivers for the situation with and without the dam.

Flow rates and water depths for the situation without the dam (i.e. natural conditions) have been established based on computation of runoff from the different sub-catchment basins corresponding to the strategic locations studied. Data from gauging stations for the period 1956 – 1986 have been used to calibrate the model.

The situation with the project has then been determined using the model developed for the natural situation and taking into account the modes of operation of the dam for storage of water and release rates at the dam site and at the powerhouse. This part of the assessment is based on the average monthly turbined flow rates established by the Owners Engineer in late 2015 (Stucky, 2015). However, after issue the first version of this study, the average monthly turbined flow rates were revised (Stucky, 2016a) and the flow rates slightly reduced. The revised flow rates are provided in section 4. However, the hydrology assessment has not integrated the revised turbined flow rates, because the changes are so small that there are no changes to the overall findings, conclusions or recommendations.

1.3.2 Geomorphology assessment

The study comprises determining relative variations in sediment transport capacity of the Nenskra and Nakra rivers on a monthly basis with and without the dam. The consequences of changes in river flow resulting from the project are then determined.

The general characteristics of the sediment in the rivers and which are input from runoff has been estimated based on expert judgement during an 8 day field visit to observe the rivers and inspect sediment.

Variation in transport capacity in percentage has been calculated for the strategic locations studied as part of the hydrological assessment and where river bed cross-sections have been measured. The transport capacity variations have been computed using the Meyer-Peter formula for the initiation of motion of the sediment, subsequent transport is computed according to the Shields theory. The approach used one of a number of models that all give generally similar results and which are most suitable for comparative purposes i.e. comparing a situation with and with a dam – and are able to indicate tendencies rather than absolute values.

1.3.3 Water quality assessment

The assessment encompasses (i) baseline survey of the water quality in Nenskra, Nakra and Enguri Rivers, (ii) prediction of water quality in the future Nenskra reservoir, Nenskra River downstream of the future dam and water quality in the Nakra River downstream of the future transfer tunnel diversion weir, (iii) estimation of project Greenhouse Gas (GHG) emissions, (iv) and identification of mitigation measures.

The baseline river water quality survey comprised taking in-situ measurements of physical parameters and taking water samples for chemical analysis at 7 river stations (3 for the Nenskra, 2 for the Nakra and 2 in the Enguri).

The predicted water quality in the reservoir has been made using a quantitative approach comprising an estimation of the input of nutrient and inorganics into the reservoir water from soils and river inflow. The quality of downstream water quality has been made using a quantitative approach and takes into account reservoir operation modes, reservoir water quality and dilution of the river from calculated inflow from tributaries. Temperature impacts have been evaluated qualitatively taking into account baseline water temperature data, reservoir operation modes and dilution effects from tributaries.

The key aspect of the reservoir water quality assessment has been to determine the risk of creating eutrophic conditions and this has been determined quantitatively by calculating estimated concentrations of Nitrogen (N) and Phosphorous (P) in the reservoir and comparing with typical concentrations for different trophic levels. Dissolved Oxygen (DO) has been calculated by determining the organic carbon in the reservoir and assuming that this is converted to carbon dioxide - producing GHG emissions – and consuming oxygen in the water – thus reducing reservoir DO.

1.3.4 Study area

1.3.4.1 Baseline hydrology

The study area for baseline hydrology encompasses the following:

- Nenskra watershed area for the confluence of the Nenskra and Enguri Rivers, and
- Nakra water shed area for the confluence of the Nakra and Enguri Rivers.

The watershed and sub-watershed areas are illustrated in the Map 2-1 in Section 2.

1.3.4.2 Baseline water quality

The study area for baseline water quality and geomorphology encompasses the following:

- Nenskra River extending from the upper reaches of the future reservoir to the upper reaches of the Enguri reservoir, some 33 kilometres downstream;
- Nakra River from the diversion weir the confluence with the Enguri River, a distance of 9 kilometres.
- Enguri River between the confluence with the Nakra and the Nenskra – a reach of 9 kilometres in length.

The study area is illustrated on Map 1-1.

1.3.5 Hydrological, geomorphological and water quality impacts

The study area hydrological, geomorphological and water quality impact assessment covers the following:

- Nenskra River downstream of the Nenskra dam and extending to the confluence with the Enguri reservoir;
- Nakra River downstream of the diversion weir and extending to the confluence with the Enguri River; and
- Enguri River extending from the confluence with the Nakra to the upper reaches of the Enguri reservoir.

1.3.5.1 Site investigations

The water quality and hydrology/geomorphology field work was carried out concurrently during the period 28 September – 7 October, 2015.

All collected water samples were transported to an accredited European laboratory for analysis. Samples were also transported to the National Environmental Agency (NEA) laboratory in Tbilisi for analysis of parameters that needed to be analysed within a time frame incompatible with the time needed for transport to Europe.

1.3.5.2 Interactions with the other E&S Supplementary Studies

The interactions with other Supplementary E&S studies issued in 2016 are as follows:

- Findings of the geomorphological impact assessment and risks associated with the geomorphological changes in the Nenskra and Nakra rivers are integrated into and developed in the Natural hazards and Dam Safety report (Volume 6). This subject is also addressed in the Social Impact Assessment (volume 3), and
- Findings of the hydrological and water quality assessments are integrated into the Social Impact Assessment (Volume 3) and the Biodiversity Impact Assessment (volume 4).

1.4 Structure of the report

The hydrology and Report is structured into the following main sections:

- **Section 1: Introduction**, provides project background, objectives, overview of methodology, study area, field investigations and interaction with other E&S studies
- **Section 2: Nenskra and Nakra watershed areas**, provides a description of the watershed of the study area, and which is used in the hydrology study to determine river flow rates with and without the project;
- **Section 3: Baseline situation**, describing field survey, equipment, methods and covering both hydrology and water quality;
- **Section 4: Operation of the hydropower scheme**, describes the reservoir operation and characterises the different inflow and outflow rates and variations in reservoir water level;
- **Section 5: Impact on downstream hydrology**, describes the river flow without the project, based on a study of the watershed, and predicted impact on the river flow taking into account presence of the dam and reservoir operation modes;
- **Section 6: Geomorphological impact assessment**, described sediment transport by the rivers with and without the project;
- **Section 7: Impact on water quality**, describes the reservoir operation, predicted changes in reservoir water quality in terms of nutrients, organic carbon, dissolved oxygen and temperature, and predicted impacts on downstream river water quality;
- **Section 8: Climate changes**, provides an overview of how climate change has been considered in the design, an estimation of greenhouse gas emissions for construction, reservoir operation, provides a comparison with dam-reservoirs worldwide, and with emissions from alternative technologies. A high level assessment of micro-climate change is included; and
- **Section 9: Synthesis of impacts, significance and commitments** provides in tabular a synthesis of all impacts on hydrology, geomorphology and water quality with ranking of impact significance, and all the mitigation measures proposed through this document.

2 Nenskra & Nakra watershed areas

2.1 General description

The Nenskra River and the Nakra River are right bank tributaries of the Enguri River. Their valleys, located on the southern slopes of the Greater Caucasus Mountains, are parallel and orientated more or less North-South.

The Nenskra River is the main tributary of the Enguri River. Its catchment area is situated with a high point of nearly 4,000 metres and encompassing 21 glaciers covering a total area of approximately 15 square kilometres. The confluence of the Nenskra with the Enguri is at an altitude of 560 metres above sea level.

Low flows are observed in winter from December to March and high flows in spring and summer from May to August.

The following maps have been used for the computation of the intermediate catchment areas and discharges along the Nenskra River and Nakra River and their main tributaries:

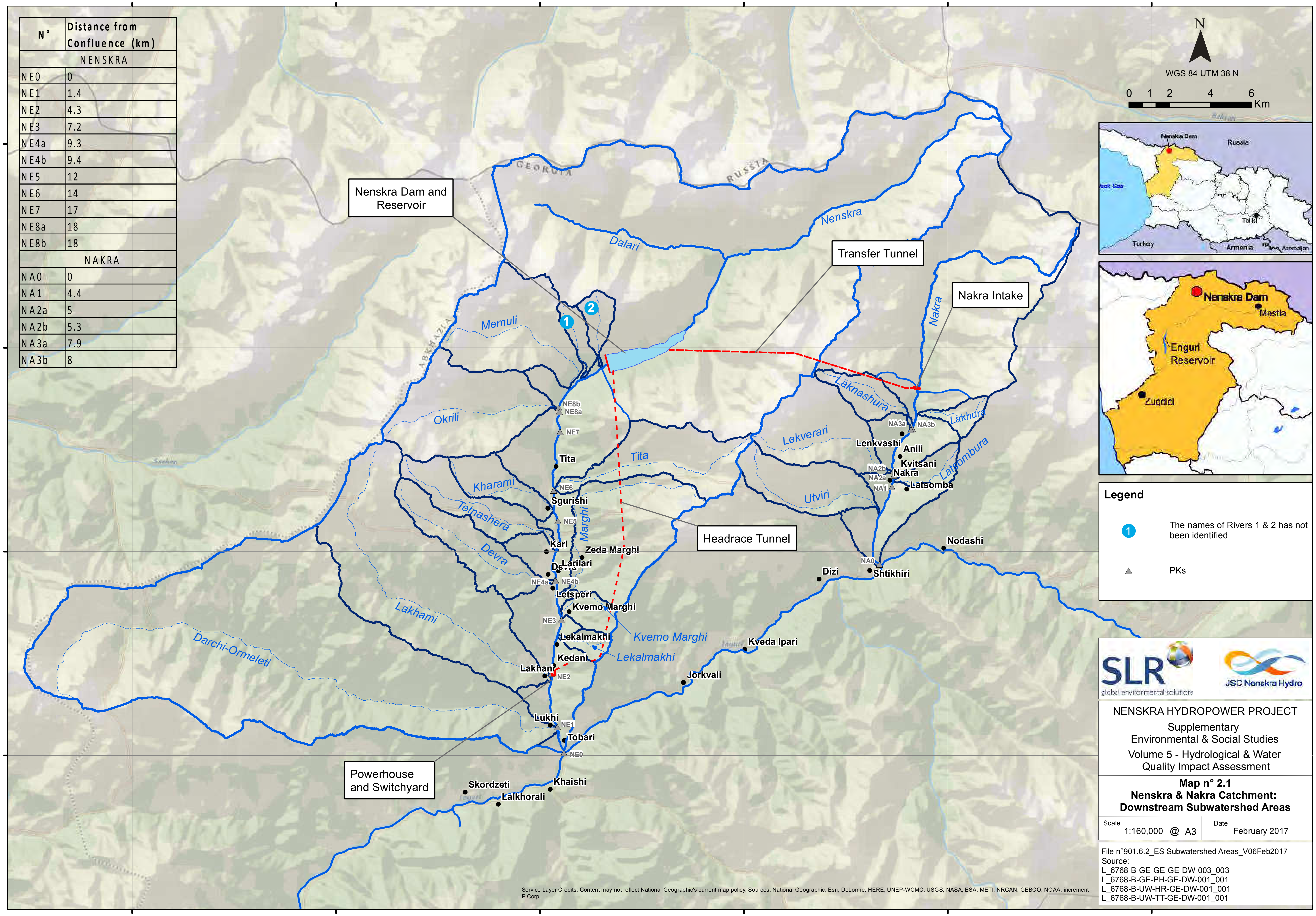
- A Digital Surface Model (DSM) of the area, developed from satellite imagery with a 5 metre resolution ;
- Topographical Maps at scale 1/25,000 and 1/50,000 which cover most of the area;
- Layout of the main Project components - dam axis on the Nenskra, diversion weir and transfer tunnel on the Nakra, powerhouse on the Nenskra, and
- Google maps covering the Nenskra River between the Enguri confluence and the end of the Nenskra reservoir and along the Nakra River between the confluence with the Enguri River and the diversion weir.

2.2 Catchment basin characteristics

The catchment areas along the rivers and the tributaries watersheds are presented Map 2-1 overleaf. Table 1 to Table 4 overleaf present the catchments areas and mean elevation at various locations of interest along the Nenskra and Nakra rivers and the catchment areas of the main tributaries. Each location indicated in the table is pinpointed on the map.

2.3 Socioeconomic aspects

The socioeconomic aspects are described in the baseline description of the Volume 3 “Social Impact Assessment” of the Supplementary E&S Studies. The main point to be taken into consideration is that local communities rely on spring water as their source of potable water. Individual household are supplied with spring water from nearby springs. Lengths of flexible piping have been installed between the springs and individual houses – and the water flows by gravity to the houses. There is no municipal water distribution system. There is no municipal sewage collection and treatment network, individual houses are equipped with septic tank and soak away systems. The fish populations in the Nenskra and Nakra Rivers comprise exclusively trout (Brown trout - *Salmo trutta morfa fario*), which is classed as LC (Least Concern) by the IUCN.



N°	Distance from Confluence (km)
NENSKRA	
NE0	0
NE1	1.4
NE2	4.3
NE3	7.2
NE4a	9.3
NE4b	9.4
NE5	12
NE6	14
NE7	17
NE8a	18
NE8b	18
NAKRA	
NA0	0
NA1	4.4
NA2a	5
NA2b	5.3
NA3a	7.9
NA3b	8

NENSKRA HYDROPOWER PROJECT

Supplementary Environmental & Social Studies

Volume 5 - Hydrological & Water Quality Impact Assessment

Map n° 2.1
Nenskra & Nakra Catchment: Downstream Subwatershed Areas

Scale 1:160,000 @ A3 | Date February 2017

File n°901.6.2_ES Subwatershed Areas_V06Feb2017
Source:
L_6768-B-GE-GE-GE-DW-003_003
L_6768-B-GE-PH-GE-DW-001_001
L_6768-B-UW-HR-GE-DW-001_001
L_6768-B-UW-TT-GE-DW-001_001

Table 1 – Nenskra River catchment area characteristics

Approx. Latitude Coordinate UTM 38N	Location	Reference on Map 2-1	Approx. Distance from Enguri (km)	Catchment Area (km²)	Catchment Mean Elevation (m asl)
4 760 150	Enguri Confluence	NE 0	0	614	2,187
	Lakhami Station			468	
4 761 400	Main Bridge	NE1	1.4	465	2,282
4 764 150	Powerhouse	NE2	4.3	402	2,351
4 766 642	Chuberi Main Bridge	NE3	7.2	391	2,384
4 768 550	Downstream Right bank tributary	NE4a	9.3	356	2,442
4 768 550	Upstream Right bank tributary	NE4b	9.4	342	2,463
4 771 715	Footbridge near main left bank spring	NE5	12.6	325	2,500
4 773 200	Small Bridge	NE6	14.3	294	2,537
4 775 700	Main Bridge Upstream Tita	NE7	17.5	283	2,576
4 776 900	Downstream Okrili tributary confluence	NE8a	18.6	280	2,583
4 777 000	Upstream Okrili tributary confluence	NE8b	18.8	252	2,594
	Dam site		21.7	222	2,650

Table 2 – Catchment area characteristics of main Nenskra river tributaries

Nenskra Bank	Name	Catchment area (km²)	Percentage tributary catchment area / all tributaries (%)	Catchment mean elevation (m asl)
Right	Darchi-Ormeleti	148.2	42.8%	1,895
Right	Lakhami	57.5	16.6%	1,913
Left	Lekalmakhi	2.4	0.7%	1,397
Left	Kvemo Marghi	3.8	1.1%	1,399
Left	Marghi	27.3	7.9%	1,953
Right	Devra	13.8	4.0%	1,931
Right	Tetnashera	11.3	3.3%	2,085
Right	Kharami	7.6	2.2%	1,960
Left	Tita	18.6	5.4%	2,366
Right	Okrili	27.7	8.0%	2,507
Right	Memuli	25.1	7.2%	2,509
Right	Watershed 1	3.0	0.9%	2,265
	Total right bank	294	85.0%	
	Total left bank	52.0	15.0%	
	Total Nenskra	346.3	100.0%	
Right	Watershed 2	3.5		2,483

Table 3 – Nakra river catchment area characteristics

Approx. Latitude Coordinate UTM 38N	Location	Reference on Map 2-1	Approx. Distance from Enguri (km)	Catchment Area (km²)	Catchment Mean Elevation (m asl)
4 769 290	Enguri Confluence	NA0	0	152	2,505
	Naki Station			126	
4 773 250	Nakra Bridge	NA1	4.4	127	2,589
4 773 785	Downstream Lekverari Confluence	NA2a	5	123	2,626
4 774 000	Upstream Lekverari Confluence	NA2b	5.3	104	2,637
4 776 100	Downstream Laknashura Confluence	NA3a	7.9	99	2,699
4 776 400	Upstream Laknashura Confluence	NA3b	8	93	2,713
4 777 774	Water intake		9.97	87	2,750

Table 4 – Catchment area characteristics of Nakra river tributaries

Nenskra Bank	Name	Catchment area (km²)	Percentage tributary catchment area/ all tributaries (%)	Catchment mean elevation (m asl)
Right	Utiviri	13.9	30.8%	2,367
Left	Latsombura	3.7	8.3%	1,892
Right	Lekverari	18.7	41.5%	2,594
Right	Laknashura	5.8	12.9%	2,490
Left	Lakhura	2.9	6.5%	2,552
	Total right bank	38.4	85.2%	
	Total left bank	6.6	14.8%	
	Total Nakra	45.0	100.0%	

3 Baseline situation

3.1 Baseline hydrology

3.1.1 Input data

The following data[1] has been used for the study:

- Daily flow rates for the Nakra River recoded at the Naki gauging station, collected from the Georgian administration and covering the period 1956-1986;
- Daily flow rates for the Mestiachala River recoded at the Mestia gauging station, collected from the Georgian administration and covering the period 1956-1986. This tributary of the Enguri River presents some similarities with the Nakra catchment area in terms of area, altitude and long-term data records;
- Monthly flow rates recoded at the Lakhami gauging station on the Nenskra River and the Naki gauging station on the Nakra River (Stucky, 2012a);
- Information concerning the hydropower scheme operation provided in a Project Technical Note (Stucky, 2015).

3.1.2 Field Survey

The dates and river reaches covered during the field survey are as following:

- The Nakra River between the water intake and the Enguri confluence (30/09/2015 and 01/10/2015);
- The Enguri River between the Nakra confluence and the upstream end of the Enguri reservoir (01/10/2015);
- The Nenskra River between the dam and the Enguri confluence (02/10/2015, 03/10/2015; 04/10/2015), and
- The alluvial fan of the main tributaries along the river surveys.

The river width for Nakra and Nenskra were measured where bridges cross the rivers. At selected locations river cross-sections were measured. Information concerning the geomorphology and sediment is provided in Section 6.

The Nenskra River/valley and the Nakra River/Valley have similar features of longitudinal slope. The mean slope of the Nenskra River, downstream of the dam, between Kilometre Point (KP) 2 and 20 is around 3.4 percent. The profile is illustrated in Figure 1. The mean slope of the Nakra River, downstream of the intake, between KP 1.9 and KP 9.7 is around 6.2 percent. The profile is illustrated in Figure 2.

[1] The Project's hydrological studies for the purpose of estimating the Maximum Probable Flood, designing the spillway and for determining power production are ongoing into the detailed design phase. Consequently flow data used in the hydrology impact assessment will differ slightly from the final hydrological data used by the Project. However, the potential scale of changes has been confirmed by the Designer and as part of this assessment it has been concluded that the slight differences that could arise will not affect the findings and conclusions presented in this volume.

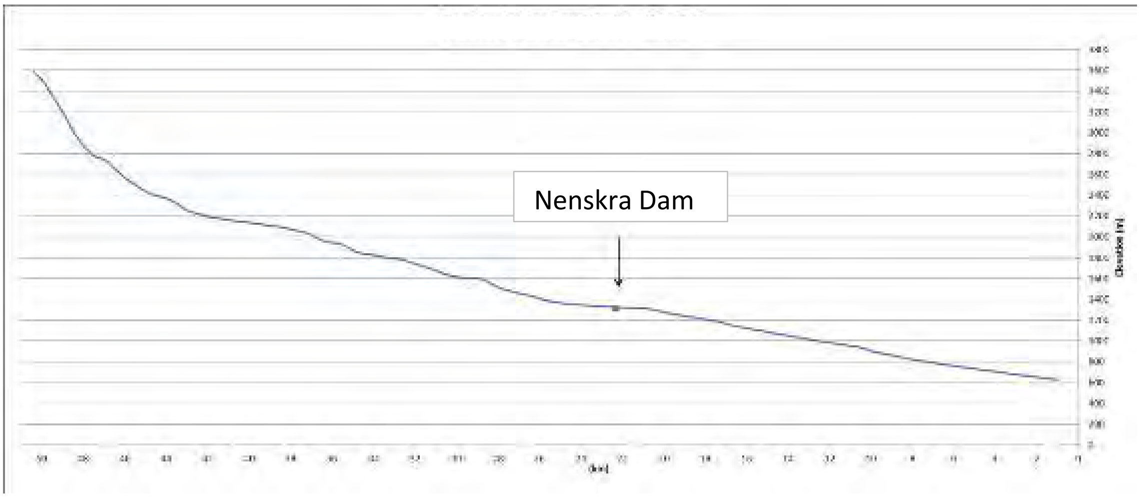


Figure 1 – Nenskra river longitudinal profile

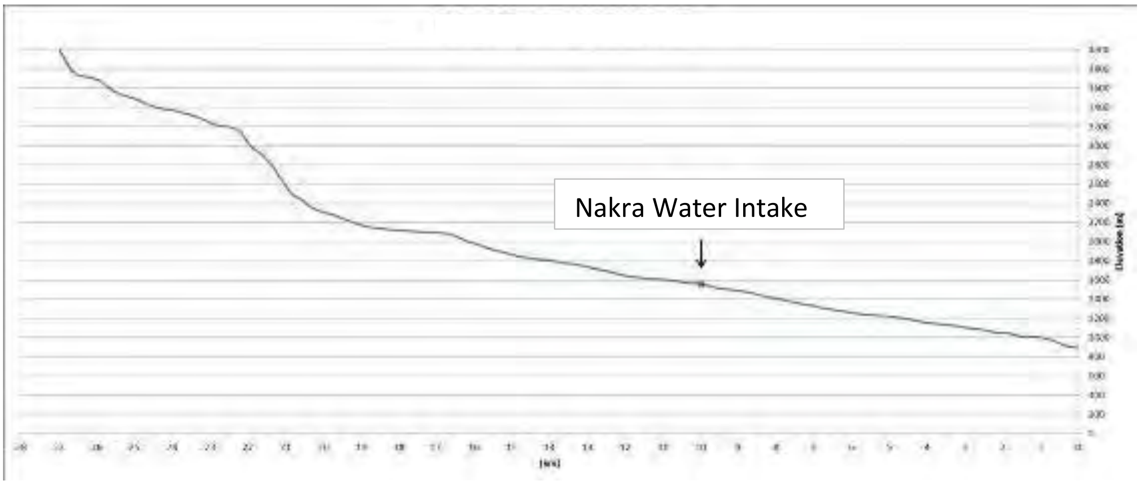


Figure 2 – Nakra river longitudinal profile

However, the slope of the Nakra River is steeper than any parts of that of the Nenskra:

- The reaches immediately upstream of the respective confluences with the Enguri River are both flow through deep, narrow and steep sided gorges. The rivers are deeply embanked and the riverbed slopes are steeper than the upstream sections:
  - About 10.5 percent for the Nakra
  - About 7 percent for the Nenskra
- Upstream the mean slopes are:
  - About 6.2 percent for the Nakra up to the water intake
  - About 3.4 percent for the Nenskra up to the dam
- Immediately upstream of the works the slopes are more gentle:
  - About 4.2 percent for the Nakra upstream of the diversion weir over 2 kilometres,
  - About 1.5 percent for the Nenskra upstream of the dam over 2.5 kilometres.

3.1.3 Observations and findings of interviews

3.1.3.1 Nakra River

From discussions with the mayor of the Nakra village, it came to light that the Lekverari tributary of the Nakra River - immediately upstream of the Nakra village and downstream from the Nakra weir - is considered as dangerous because of past events which are described below.

Beginning of August 2011, an unusually heavy rain storm triggered a landslide in the gorge through which the Lekverari flows and which is located 1 or 2 kilometres upstream of the Nakra village. The location of the landslide is illustrated in Figure 3 overleaf.

The Lekverari was in flood at the time and transported a large amount of sediment from the landslide downstream to the confluence with the Nakra River, and blocked the Nakra by creating a natural dam. Within a few minutes flooding had occurred upstream extending some 800 metres. The location of the river blockage and temporarily flooded area is illustrated in Figure 3 overleaf.

Within about 5 minutes of the flooding, the hydraulic loading from the accumulated water burst the blockage and caused a wave of water to descend the river, though without causing any flooding. The natural flow of the Nakra River then progressively flushed away much of the remaining sediment.

The mayor considers that the Nakra River plays an important role in flushing of accumulated sediment that continues to be transported to the Nakra by the Lekverari. The village fears that in the case of a similar event to that of 2011, the reduced flow of the Nakra (as a result of the Project) could reduce the river's flushing capacity and the village will continue to be exposed to events similar to those of 2011. The river's capacity to flush the sediment is an important function of the river and the Project will need to ensure that this function is maintained.

The mayor and the village community expect a widening and realigning of the current natural bed of the Nakra River in the area of the confluence with the Lekverari, the realignment would stop the current erosion of the foot of the left bank slope and prevent damage to field that are above the slope and which are currently threatened by the slope instability caused by the erosion. The realignment is illustrated in Figure 4.

3.1.3.2 Nenskra River

From a discussion with local people, including the mayor of Chuberi, it emerges that there is concern among local people that the reservoir could modify the local climate, causing increased precipitation (rain and snow). In 1987, a large avalanche occurred impacting part of the village and causing some fatalities. Consequently many of the village people moved out the Nenskra valley. In the 1980's there were in the order of 500 families living in the village of Chuberi, there are now (2015) 273 households.

Floods and sediment transport are not considered a problem for the village. During floods, the river flushes away accumulated sediment transported from upstream.

Figure 3 – Localisation of Nakra mudflow events in 2011

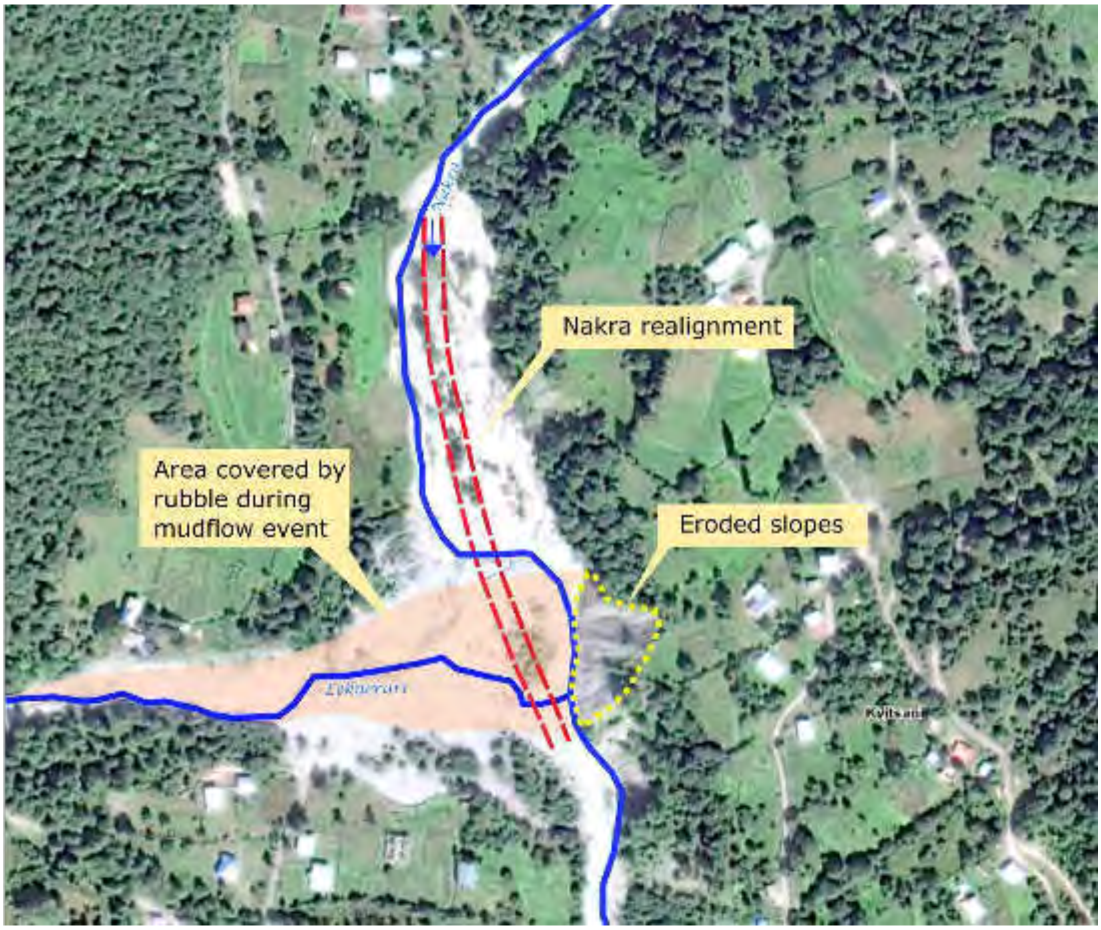


Figure 4 – Realignment of Nakra expected by people of Nakra village (2015)

Lekverari torrent
Photo taken from Nakra village.
2011 landslide visible in upstream gorge

Lekverari torrent at Nakra village – looking downstream to the confluence with Nakra

Lekverari gorge - zone exposed to landslide risk

Nakr River – at Nakra village – remains of solid material transported by Lekverari torrrent followin g landslide in 2011 – and which blocked the Nakra
Illustrates the depth of material that blocked the river

Lekverari torrent aluvial fan at confluence with Nakra River

Lekverari torrent aluvial fan at confluence with Nakra River

Photo Sheet 1– Geomorphology features at the Lekverari - Nakra confluence


Downstream branch of the Laknashura torrent – road crossing near confluence with Nakra


Upstream branch of Laknashura torrent – road crossing near confluence with Nakra


Evidence of landslide on left bank of Nakra – upstream of Nakra diversion weir


Laknashura torrent – road crossing near confluence with Nakra – looking down at the Nakra


Nakra right bank – this torrent discharges into the Nakra about 500 metres upstream of diversion weir


Unnamed torrent on the left bank of the Nakra valley in the vicinity of the diversion weir – setback up the valley about 300 metres.

Photo Sheet 2 - Geomorphology features at the Laknashura – Nakra confluence

Downstream branch of the Laknashura torrent – road crossing near confluence with Nakra

Upstream branch of Laknashura torrent – road crossing near confluence with Nakra

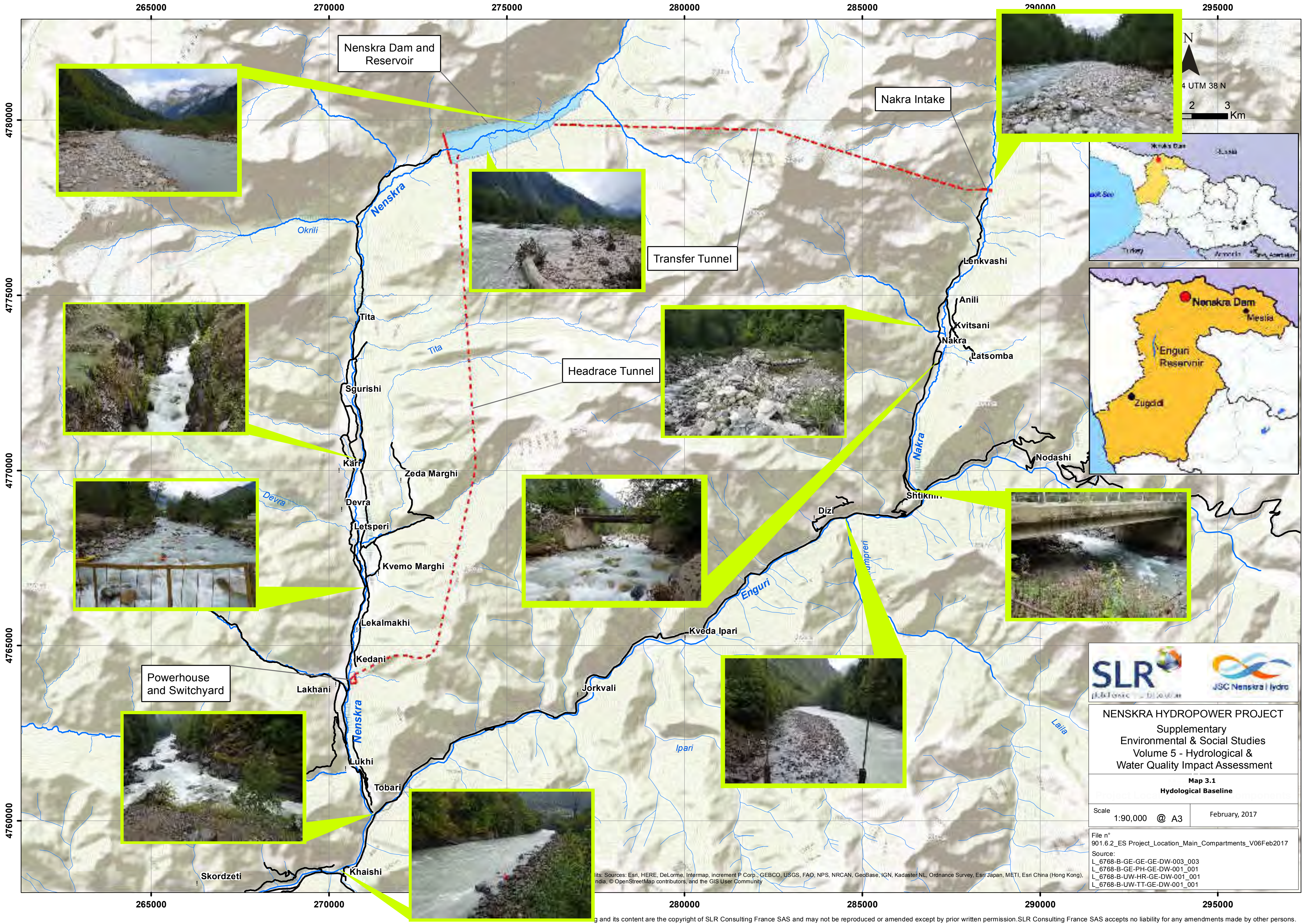
Evidence of landslide on left bank of Nakra – upstream of Nakra diversion weir

Laknashura torrent – road crossing near confluence with Nakra – looking down at the Nakra

Nakra right bank – this torrent discharges into the Nakra about 500 metres upstream of diversion weir

Unnamed torrent on the left bank of the Nakra valley in the vicinity of the diversion weir – setback up the valley about 300 metres.

Photo Sheet 3– Geomorphology features at the Nenskra dam site, reservoir and upstream



265000
270000
275000
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285000
290000
295000
4780000
4775000
4770000
4765000
4760000
Nenskra Dam and Reservoir
Nakra Intake
Transfer Tunnel
Headrace Tunnel
Powerhouse and Switchyard
Nenskra
Okrili
Tita
Devra
Nakra
Enguri
Ipari
Laila
Lenkvashi
Anili
Kvitsani
Nakra
Latsomba
Nodashi
Shtikhiri
Dizi
Kveda Ipari
Jorkvali
Tita
Sgurishi
Kari
Zeda Marghi
Devra
Letsperi
Kvemo Marghi
Lekalmakhi
Kedani
Lakhani
Lukhi
Tobari
Khaishi
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2
3
Km
Nenskra Dam
Mestia
Enguri Reservoir
Zugdidi
SLR
JSC Nenskra Hydro
NENSKRA HYDROPOWER PROJECT
Supplementary Environmental & Social Studies
Volume 5 - Hydrological & Water Quality Impact Assessment
Map 3.1
Hydrological Baseline
Scale
1:90,000 @ A3
February, 2017
File n°
901.6.2_ES Project_Location_Main_Compartments_V06Feb2017
Source:
L_6768-B-GE-GE-GE-DW-003_003
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Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), India, © OpenStreetMap contributors, and the GIS User Community

3.1.4 Assessment methodology

The study concerns the monthly hydrology of:

- The Nenskra River between the dam and the Enguri confluence, and
- The Nakra River between the water intake and the Enguri confluence.

The methodology of the study is as follows:

- Computation of the catchment areas and mean elevation for a number of strategic locations along the Nakra and Nenskra rivers;
- Computation of mean annual runoff corresponding to the locations of the gauging stations (Naki on Nakra River, Lakhami on Nenskra River) over the period 1956-1986;
- Determination of the annual unit discharges ($m^3/s/ha$) of the catchment areas of the strategic locations based on the mean elevation of the catchment areas reported in the regional Caucasus study chart (Trans-Caucasian Hydro-Meteorological Research Institute, 1967);
- Computation of the mean monthly discharges at the various strategic locations for the baseline conditions (current state) and for the situation with the dam (future state);

A comparison of computed and measured data (from gauging stations) for strategic points on the rivers was made to validate assumptions and methodology. The computed mean annual flow of the Nenskra compares well with measured data – the computed value is the same at the measured value. For the Nakra River, the value from the gauging station is 14 percent less than the value computed using regional Caucasus study chart. Consequently, as a precautionary the values from the gauging station have been used in the assessment.

The impact of the project is computed along the rivers taking into account:

- The variation of the natural runoff caused by the modifications of the catchment areas boundaries, including:
  - Reduced catchment area upstream of the Nakra water intake and upstream of the Nenskra dam, and
  - Variation (lowering) of the mean elevation of the reduced catchment areas which impacts the runoff (calculated from the regional study chart).
- The hydropower scheme operation which includes:
  - Mandatory Ecological flows maintained in the rivers downstream of the works (Nakra dam: 1.2 m^3/s; Nenskra dam: 0.85 m^3/s).
  - Energy production: turbined water flows discharged from the powerhouse to the Nenskra.
- Monthly flows at the strategic locations are calculated using the ratios of annual: monthly flow established for the gauging stations.

3.1.5 River flows at strategic locations

The following tables present the mean monthly discharges computed at the strategic locations. The strategic locations are locations where main bridges, villages, works (dam, intake, power plant) are encountered. There were decided by the hydrology team as well as the fish impact assessment team. They are located on Map 2-1 page 8.

Table 5 – Nenskra River flow under natural conditions at strategic locations

Location on Map 2-1	Catchment area parameters				Average Annual Flow (m^3/s)		Average Monthly Flow (m^3/s)											
	Location	Approx. Distance from Enguri confluence (km)	Catchment Area (km^2)	Catchment Mean Elevation (m asl)	Unit annual discharge for Caucasus region[a] ($l/s/km^2$)	Mean Annual Discharge according regional Caucasus analysis[a] m^3/s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NE0	Enguri Confluence	0	614	2,187	60	36.8	9.7	9.2	12.4	35.1	72.9	86.4	80.7	52.2	32.7	22.3	16.3	12.4
	Lakhami Station		468		64	30.0	7.9	7.5	10.1	28.5	59.3	70.3	65.6	42.4	26.6	18.1	13.3	10.1
NE1	Main Bridge	1.4	465	2,282	64	29.7	7.8	7.4	10.0	28.3	58.9	69.7	65.1	42.1	26.4	18.0	13.2	10.0
NE2	Power Station	4.3	402	2,351	66	26.5	7.0	6.6	8.9	25.3	52.5	62.3	58.1	37.6	23.6	16.1	11.8	8.9
NE3	Chuberi Main Bridge	7.2	391	2,384	66	25.8	6.8	6.5	8.7	24.6	51.1	60.5	56.5	36.5	22.9	15.6	11.4	8.7
NE4a	Downstream confluence with Devra	9.3	356	2,442	68	24.2	6.4	6.1	8.1	23.0	47.9	56.7	53.0	34.2	21.5	14.6	10.7	8.1
NE4b	Upstream confluence with Devra	9.4	342	2,463	68	23.3	6.1	5.8	7.8	22.1	46.0	54.5	50.9	32.9	20.7	14.1	10.3	7.8
NE5	Footbridge near main left bank spring	12.6	325	2,500	70	22.7	6.0	5.7	7.6	21.6	45.0	53.3	49.7	32.2	20.2	13.7	10.1	7.6
NE6	Small Bridge	14.3	294	2,537	71	20.9	5.5	5.2	7.0	19.9	41.4	49.0	45.8	29.6	18.6	12.6	9.3	7.0
NE7	Main Bridge Upstream Tita	17.5	283	2,576	72	20.3	5.4	5.1	6.8	19.4	40.3	47.7	44.6	28.8	18.1	12.3	9.0	6.8
NE8a	Downstream Okrili tributary confluence	18.6	280	2,583	72	20.2	5.3	5.1	6.8	19.2	40.0	47.3	44.2	28.6	17.9	12.2	8.9	6.8
NE8b	Upstream Okrili tributary confluence	18.8	252	2,594	73	18.4	4.9	4.6	6.2	17.5	36.5	43.2	40.3	26.1	16.4	11.1	8.2	6.2
	Dam site Downstream confluence stream n°2	21.7	222	2,650	74	16.5	4.3	4.1	5.5	15.6	32.5	38.5	36.0	23.3	14.6	9.9	7.3	5.5
	Dam site Upstream Confluence Stream n°2	21.7	218.5	2,650	74	16.2	4.3	4.1	5.4	15.4	32.0	38.0	35.4	22.9	14.4	9.8	7.2	5.4

[a]: Run-off per hectare reported in literature for the Caucasus Mountains – Trans-Caucasian Hydro-Meteorological Research Institute, 1967

Table 6 – Nakra River flow under natural conditions at strategic locations

Location on Map 2-1	Catchment area parameters				Average annual flow (m^3/s)		Average monthly flow (m^3/s)											
	Location	Approx. Distance from Enguri confluence (km)	Catchment Area (km²)	Catchment Mean Elevation (m asl)	Unit annual discharge for Caucasus region[a] (l/s/km²)	Mean Annual Discharge according regional Caucasus[a] analysis (m^3/s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NA0	Enguri Confluence	0	152	2,505	88	13.4	3.3	3.1	3.6	10.0	20.5	26.5	27.5	19.3	11.1	7.4	5.4	4.0
	Naki Station		126		99	12.5	3.0	2.9	3.3	9.4	19.1	24.7	25.7	18.0	10.4	6.9	5.0	3.7
NA1	Nakra Bridge	4.4	127	2,589	99	12.6	3.1	2.9	3.3	9.4	19.2	24.9	25.9	18.1	10.5	7.0	5.1	3.7
NA2a	Downstream Lekverari Confluence	5.0	123	2,626	102	12.6	3.1	2.9	3.3	9.4	19.2	24.9	25.9	18.1	10.5	7.0	5.1	3.7
NA2b	Upstream Lekverari Confluence	5.3	104	2,637	108	11.3	2.7	2.6	3.0	8.5	17.2	22.3	23.2	16.2	9.4	6.2	4.5	3.3
NA3a	Downstream Laknashura Confluence	7.9	99	2,699	110	10.9	2.7	2.5	2.9	8.2	16.7	21.6	22.5	15.7	9.1	6.0	4.4	3.2
NA3b	Upstream Laknashura Confluence	8.0	93	2,713	110	10.3	2.5	2.3	2.7	7.7	15.7	20.3	21.2	14.8	8.5	5.7	4.1	3.0
	Water Intake	9.97	87	2,750	113	9.2	2.4	2.2	2.6	7.4	15.0	19.5	20.3	14.2	8.2	5.4	4.0	2.9

[a]: Run-off per hectare reported in literature for the Caucasus Mountains – Trans-Caucasian Hydro-Meteorological Research Institute, 1967

3.2 Baseline water quality

3.2.1 Input data

All input data for establishment of the baseline situation is primary data that was collected by SLR during a water quality survey.

3.2.2 Field Survey

3.2.2.1 Introduction

The purpose of the water quality survey was to collect additional data to complement the water quality data collected by Gamma as part of the Nenskra Project's 2015 ESIA. The survey was carried-out during the period 28 September – 7 October, 2015.

The water quality monitoring that has been carried out is considered to be sufficient to characterise the baseline water quality as it is expected that there is little inter-annual and inter-seasonal variation in surface water quality. This is because the Nenskra catchment area encompasses a mountainous area where vegetation is sparse at altitudes above 1,500 metres and for most of the year the surface water comprises snow and glacial melt water. It is expected that probably the autumn period - when the sampling was undertaken - is the season when the highest concentrations of nutrients and organic matter can be observed in the surface water. The nutrients and organic matter originate from the biodegrading of vegetation in the catchment area. The surface water quality was found to be typical of pristine mountain stream water in granitic areas.

All collected water samples were transported to an accredited European laboratory for analysis. Samples were also transported to the National Environmental Agency (NEA) laboratory in Tbilisi for analysis of parameters that needed to be analysed within a time frame incompatible with the time needed for transport to Europe.

3.2.2.2 Survey area

The survey area was defined in order to establish baseline water quality conditions of the Nenskra, Nakra and Enguri Rivers at strategic. The study area is defined as follows:

- Nenskra River upstream of the future dam and corresponding to the impounded area of the future reservoir;
- Nenskra River downstream of the future dam and extending to the confluence with the Enguri River;
- Nakra River immediately upstream of the future water diversion weir;
- Nakra River downstream of the future water diversion weir and extending to the confluence with the Enguri River;
- The Enguri River downstream of the confluence with the Nakra River and extending to the confluence with the Nenskra River extending a few kilometres further downstream.

3.2.2.3 Survey programme

The survey programme is presented in the following table. The programme required the first days to be spent on reconnaissance to identify suitable sampling stations that could be accessed safely. Once all sample stations had been identified, the samples were all collected in 1 day and transport to Tbilisi and then on to the laboratory for analysis.

Table 7 –Survey day-to-day programme

Date	Activity
Monday, Sept. 28	Organisation of laboratory analysis in Tbilisi at the Environmental Protection Agency Laboratory, organisation of travel logistics
Tuesday, Sept. 29	Travel to Project site
Wednesday, Sept. 30	Reconnaissance of the Nakra river upstream of from Nakra village and extending to the future weir site and 2 kilometres further upstream. Sampling stations with ease of access were identified and in-situ water quality measurements taken
Thursday, Oct. 1	Reconnaissance of the following reaches – identification of sampling stations with suitable ease of access and in-situ measurements • Nakra River downstream from Nakra village and extending to the confluence with the Enguri • Enguri river from the confluence with the Nakra to Kaishi • Nenskra river from the confluence with the Enguri to Chuberi
Friday, Oct. 2	Reconnaissance of the Nenskra river between Tita and Chuberi - – identification of sampling stations with suitable ease of access and in-situ measurements.
Saturday, Oct. 3	Reconnaissance of the Nenskra river upstream of Tita at the dam site and in the future reservoir area – identification of sampling stations with suitable ease of access and in-situ measurements.
Sunday, Oct. 4	Travel to all the sampling stations identified during the previous 4 days – and collection of water samples at each sampling station. All samples were placed in a cool box ready for transport to Tbilisi and then to Europe by air.
Monday, Oct. 5	Water samples were transport by road to Tbilisi and handed over to DHL for air transport
Tuesday, Oct. 6	Repeat of the work carried out on October 4, to collect samples to be analysed in Tbilisi. These samples were for analysis of parameters requiring analysis within 24 hours and thus analysis in Europe not feasible. The sampling was carried out after the previous sampling due to logistics problems regarding the transport of cool boxes and sampling bottles from Tbilisi to the site.
Wednesday, Oct. 7	Water samples were transported by road to Tbilisi and handed over to the NEA laboratory.

3.2.2.4 Location of sampling stations

The locations of sampling stations were selected taking into account the following:

- Need for samples at locations upstream and downstream of the dam and weir structures,
- Need for samples upstream and downstream of confluences,
- Safe access to sampling stations, some sections of the rivers represented serious access difficulties because of steep and unstable banks, river gorge sections were totally inaccessible.

The selected sampling stations are presented in table and illustrated on Map 3-2 and Table 8.

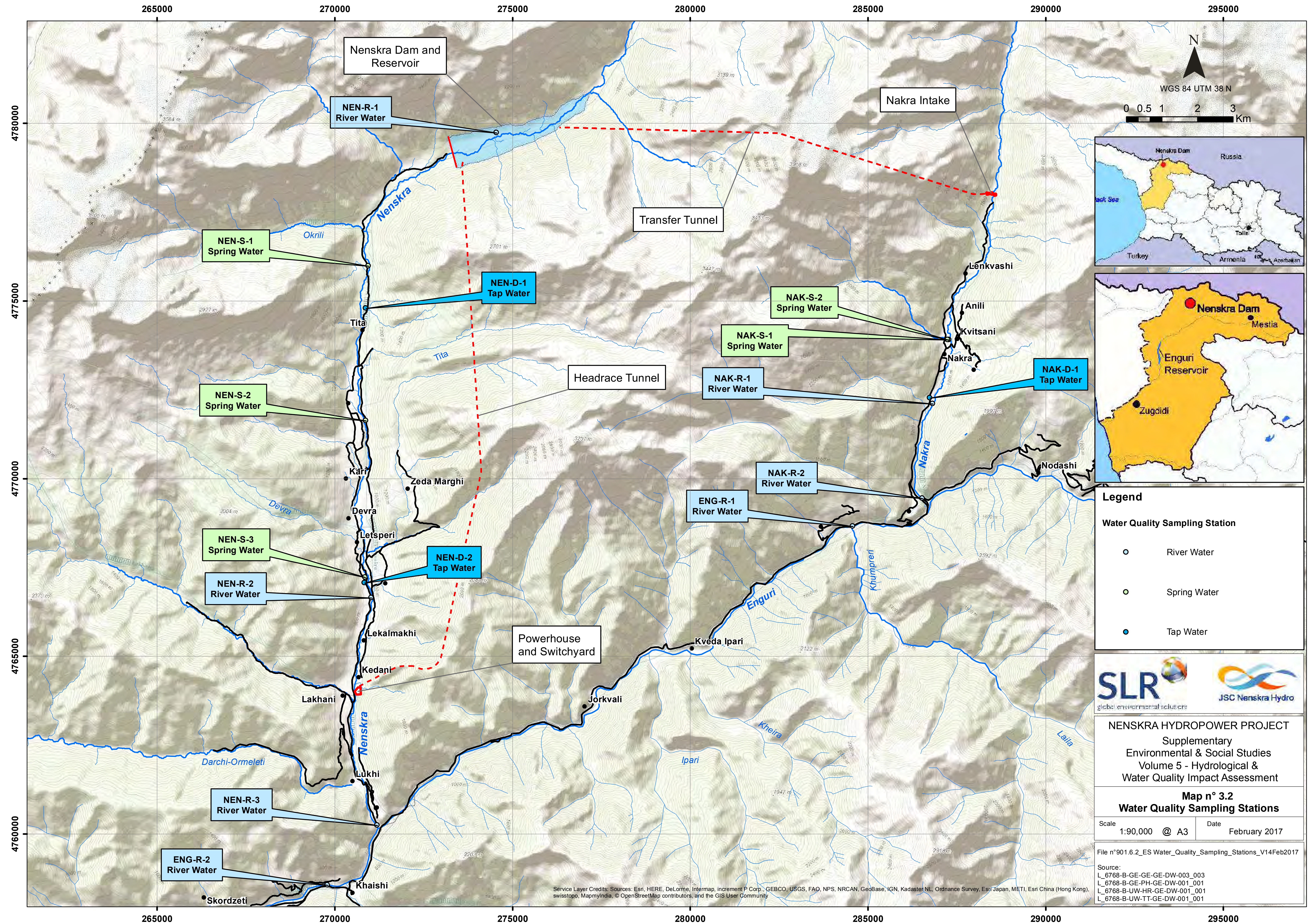

Nenskra Dam and Reservoir
NEN-R-1 River Water
Nakra Intake
Transfer Tunnel
NEN-S-1 Spring Water
NEN-D-1 Tap Water
NAK-S-2 Spring Water
NAK-S-1 Spring Water
Headrace Tunnel
NAK-R-1 River Water
NAK-D-1 Tap Water
NEN-S-2 Spring Water
NAK-R-2 River Water
ENG-R-1 River Water
NEN-S-3 Spring Water
NEN-D-2 Tap Water
NEN-R-2 River Water
Powerhouse and Switchyard
NEN-R-3 River Water
ENG-R-2 River Water
Nenskra
Okrili
Tita
Kari
Zeda Marghi
Devra
Letsperi
Lekalmakhi
Kedani
Lakhani
Lukhi
Khaishi
Skordzeti
Darchi-Ormeleti
Lenkvashi
Anili
Kvitsani
Nakra
Nodashi
Enguri
Khumpreri
Kveda Ipari
Jorkvali
Kheira
Ipari
Laila
N
WGS 84 UTM 38 N
0 0.5 1 2 3 Km
Nenskra Dam
Russia
Black Sea
Turkey
Armenia
Azerbaijan
Tbilisi
Mestia
Enguri Reservoir
Zugdidi
Legend
Water Quality Sampling Station
River Water
Spring Water
Tap Water
SLR global environmental solutions
JSC Nenskra Hydro
NENSKRA HYDROPOWER PROJECT
Supplementary Environmental & Social Studies
Volume 5 - Hydrological & Water Quality Impact Assessment
Map n° 3.2
Water Quality Sampling Stations
Scale 1:90,000 @ A3
Date February 2017
File n°901.6.2_ES Water_Quality_Sampling_Stations_V14Feb2017
Source:
L_6768-B-GE-GE-GE-DW-003_003
L_6768-B-GE-PH-GE-DW-001_001
L_6768-B-UW-HR-GE-DW-001_001
L_6768-B-UW-TT-GE-DW-001_001
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
265000
270000
275000
280000
285000
290000
295000
4780000
4775000
4770000
4765000
4760000

Table 8 –Sampling stations – coordinates and description

Ref.	Type sample	Coordinates		Location description
NEN-R-1	Nenskra river	0274552	4779729	Future reservoir area
NEN-R-2	Nenskra river	0271029	4766640	Immediately downstream Chuberi
NEN-R-3	Nenskra river	0271196	4760238	Immediately upstream confluence with Enguri
NAK-R-1	Nakra river	0286829	4772098	Nakra village
NAK-R-2	Nakra river	0286534	4769438	Immediately upstream confluence with Enguri
ENG-R-1	Enguri river	0284584	4768649	Mid distance between Nakra & Nenskra confluences
ENG-R-2	Enguri river	0269798	4758550	Immediately downstream Kaishi
NEN-S-1	Nenskra valley mineral water spring	0270951	4775972	Near Tita (upstream of village)
NEN-S-2	Nenskra valley mineral water spring	0270877	4771627	Mid distance between Tita and Chuberi
NEN-S-3	Nenskra valley drinking water spring	0270857	4767214	In Chuberi
NAK-S-1	Nakra valley mineral water spring	0287290	4773896	Next to Nakra river in Nakra village
NAK-S-2	Nakra valley drinking water spring	0187250	4773900	In Nakra village
NEN-D-1	Nenskra valley household tap water	0270880	4774787	Household in Tita
NEN-D-2	Nenskra valley household tap water	270839	4767062	Household in Chuberi
NAK-D-1	Nakra valley household tap water	286744	4772266	Household in Nakra

Photographs of sampling stations are provided in the Photo Sheet 4 and Photo Sheet *5* on following pages.

3.2.3 Material and methods

In-situ measurements were carried out using the following:

- Portable pH, Electrical Conductivity, Temperature probe. Hanna Instruments Combo HI 98129/130, and
- Portable Dissolved Oxygen meter, Hanna Instruments HI 9147.

Both instruments were newly purchased in France and transported to the site by the water quality expert. The instruments were calibrated on site using newly purchased standard solutions.

Figure 5 – Photo of measuring devices for in-situ measurements

Sampling Station NEN-S-1
Mineral Water Spring upstream of Tita
Note rust colour of rocks

Sampling Station NEN-S-1
Mineral Water Spring upstream of Tita
Note gas bubbles

Sampling Station NEN-S-2
Mineral water spring between Tita and Chuberi.
Plastic Bottles being filled by local people, and Survey sampling bottles for chemical analysis in cardboard box

Sampling Station NAK-S-1
Drinking water spring in Nakra village
Note PVC pipe to collect and drain water to nearby households

Sampling Station NEN-S-2
Mineral Water Spring between Tita and Chuberi

Sampling Station NEN-S-3
Drinking water spring in Chuberi
Note PVC pipe to collect and drain water to nearby households

Photo Sheet 4– Sampling stations for mineral water and drinking water springs

Sampling Station NEN-R-1
Nenskra river – branch in future reservoir area

Sampling Station NEN-R-3
Nenskra river – upstream of confluence with Enguri river

Sampling Station ENG-R-1
Enguri river between confluences with Nakra and Nenskra rivers

Sampling Station NEN-R-2
Nenskra river downstream of Chuberi village

Sampling Station ENG-R-2
Enguri River downstream Kaishi

Sampling Station NAK-R-2
Nakra river iupstream of confluence witth Enguri river

Photo Sheet 5– *River sampling stations*

3.2.4 In situ and laboratory analysis results

Table 9 – In-situ measurement results – Sept/Oct 2015

Ref	Type of sample	Temp. (°C)	pH	Cond. (µS/cm)	DO (mg/l)	Observations
NEN-R-1	Nenskra river	8.5	7.84	50	10.7	Clear, no SS
NEN-R-2	Nenskra river	12.3	8.06	64	10.4	Clear, no SS
NEN-R-3	Nenskra river	12.0	7.92	74	10.5	Clear, no SS
NAK-R-1	Nakra river	10.2	7.3	91	10.3	Clear, no SS
NAK-R-2	Nakra river	10.8	8.03	83	10.6	Clear, no SS
ENG-R-1	Enguri river	9.1	8.1	132	11.2	Clear, no SS
ENG-R-2	Enguri river	11.0	8.16	127	11.1	Clear, no SS
NEN-S-2	Nenskra valley mineral water spring	12.0	6.32	1,733	1.6	Clear, no SS
NEN-S-3	Nenskra valley drinking water spring	11.08	7.05	190	7.0	Clear, no SS
NEN-D-1	Nenskra valley household tap water	11	7.68	156.2	14.4	Springwater
NEN-D-2	Nenskra valley household tap water	17.3	8.04	219	9.9	Springwater
NAK-D-1	Nakra valley household tap water	11.0	7.68	176	14.4	Springwater

Source: JSC Nenskra Hydro

Table 10 – Laboratory analysis of river water samples – Sept./Oct. 2015

Parameter	Units	NEN-R-1	NEN-R-2	NEN-R-3	NAK-R-1	NAK-R-2	ENG-R-1	ENG-R-2	EQS
Total Organic Carbon	mg/l	<0.5	<0.5	0.50	0.51	0.69	<0.5	0.79	---
Metals									
Calcium	meq/l	0.36	0.46	0.54	0.69	0.65	1.0	0.95	---
Mercury	µg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05 [a d]
Magnesium	meq/l	0.16	0.2	0.25	0.25	0.24	0.52	0.49	---
Total Hardness	meq/l	1.5	1.8	2.2	2.6	2.5	4.3	4.1	---
Inorganics									
Ammonium	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	---
Ammonium (N)	mgN/l	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	---
Phosphorus	µg/l	<50	<50	<50	<50	<50	<50	<50	---
Other Chemical and Biological Analysis									
Chlorides	mg/l	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	350 [b]
Nitrites	mg/l	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	---
Nitrites (N)	mgN/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---
Nitrate	mg/l	<0.75	<0.75	<0.75	0.81	0.83	0.81	0.75	50 [c]
Nitrate (N)	mgN/l	<0.17	<0.17	<0.17	0.18	0.19	0.18	<0.17	---
Sulphates	mg/l	8.8	8.7	9.6	10	10	21	19	---
(Ortho)phosphate	mgP/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	---
Alkalinity (as CaCO3)	mgCO3/l	<25	<25	29	33	35	50	46	---
Total Alkalinity	meq/l	<0.5	<0.5	0.6	0.7	0.7	1.0	0.9	---
Biological Oxygen Demand	mg/l	0.85	0.95	0.96	1.17	0.72	0.93	0.84	30 [b]
Chemical Oxygen Demand	mg/l	3.92	5.68	4.9	5.88	3.92	4.9	3.92	6 [b]
Total Coliforms in 300 ml	N°	10	65	40	37	41	27	49	---

Source: JSC Nenskra Hydro

Notes:

meq/l: milliequivalent per litre

EQS: Environmental Quality Standard

[a] : EU Water Framework Directive, 2000

[b] : Ministerial Order #130 Protection of Georgian Surface Water, 17 September 1996

[c]: EU Nitrates Directive, 1991

[d]: Value is 0.53 in Ministerial Order #130 Protection of Georgian Surface Water, 17 September 1996

--- : not applicable

Table 11 – Laboratory analysis of river water samples – Oct. 2011

Parameter	Units	NEN-R-3	NEN-R-2	NAK-R-2	EQS
Calcium	mg/l	13.1	12.8	31	---
Magnesium	mg/l	4.1	4.6	6.6	---
Ammonium	mg/l	<0.02	<0.02	<0.02	---
Phosphates	mg/l	<0.02	<0.02	<0.02	---
Chlorides	mg/l	5.6	5.6	5.7	350 [b]
Nitrites	mg/l	<0.02	<0.02	<0.02	50 [c]
Nitrate	mg/l	1.1	1.2	1.1	---
Sulphates	mg/l	9.7	9.7	13.2	---
Alkalinity (as CaCO3)	mgCO3/l	<0.05	<0.05	<0.05	---
Chemical Oxygen Demand	mg/l	**16.7**	**13.8**	**11.6**	6 [b]

Source: JSC Nenskra Hydro

Notes:

EQS: Environmental Quality Standard

Values in **Bold** text – indicate exceedance of EQS limit value

[a] : EU Water Framework Directive, 2000

[b] : Order #130 on Protection of Georgian Surface Water, 17 September 1996 and Sanitary Rules and Standards on prevention of Surface Water Pollution approved by order #297/n on Approval of Environmental Qualitative Norms, 16th August 2001

[c]: EU Nitrates Directive, 1991

[d]: Value is 0.53 in Ministerial Order #130 Protection of Georgian Surface Water, 17 September 1996

--- : not applicable

Table 12 – Laboratory analysis of drinking water samples – Sept./Oct. 2015

Parameter	Units	NEN-D-1	NEN-D-2	NAK-D-1	EQS EU [a]	EQS Georgian [b]
Total Organic Carbon	mg/l	<0.5	<0.5	<0.5	---	---
Metals						
Aluminium	µg/l	<50	<50	<50	200	---
Antimony	µg/l	<2.0	<2.0	<2.0	5	---
Arsenic	µg/l	<5	<5	<5	10	100
Beryllium	µg/l	<15	<15	<15	---	---
Boron	µg/l	<50	<50	<50	1	500
Cadmium	µg/l	<0.20	<0.20	<0.20	5.0	3.0
Calcium	meq/l	1	1	1	---	---
Chromium	µg/l	<1	<1	<1	50	---
Copper	µg/l	<0.2	<0.2	<0.2	2.0	2,000
Mercury	µg/l	<0.05	<0.05	<0.05	1.0	6.0
Lead	µg/l	<0.2	<0.2	<0.2	10	10
Magnesium	meq/l	0.65	1	0.77	50	---
Molybnium	µg/l	<2	<2	<2	---	---
Nickel	µg/l<	<3	<3	<3	20	70
Selenium	µg/l	<3.9	<3.9	<3.9	10	10
Iron	µg/l	<50	<50	<50	200	---
Zinc	µg/l	<10	<10	<10	---	3,000
Total Hardness	meq/l	2.1	2.1	2.1	---	---
Inorganics						
Ammonium	mg/l	<0.2	<0.2	<0.2	0.5	---
Ammonium (N)	mgN/l	<0.15	<0.15	<0.15	---	---
Fluorides	µg/l	<0.2	<0.2	<0.2	---	---
Other Analysis						
Chlorides	mg/l	<0.3	<0.3	<0.3	250	250
Nitrites	mg/l	<0.3	<0.3	<0.3	0.5	---
Nitrites (N)	mgN/l	<0.1	<0.1	<0.1	---	---
Nitrate	mg/l	0.96	0.98	1.4	50	---
Nitrate (N)	mgN/l	0.22	0.22	0.32	---	---
Sulphates	mg/l	13	18	11	250	250
Alkalinity (as CaCO3)	mgCO3	79	97	78	---	---
Total Alkalinity	meq/l	1.6	1.9	1.6	---	---
Biological Oxygen Demand	mg/l	1.04	0.99	0.96	---	---
Chemical Oxygen Demand	mg/l	3.92	5.88	4.9	---	---
Total Coliforms in 300 ml	N°	**9**	**4**	**69**	---	---

Source: JSC Nenskra Hydro

Notes:

meq/l: milliequivalent per litre

EQS: Environmental Quality Standard

Values in **Bold** text – indicate exceedance of EQS limit value

[a] : EU Directive 98/83/EC , 3rd November 1998 – on the quality of water intended for human consumption

[b] : Technical Regulations for Drinking Water approved by Order #349/n dated 17th December 2007

--- : not applicable

Table 13 – Laboratory analysis of spring water samples

Parameter	Units	NEN-S-1*	NEN-S-2*	NEN-S-3	NAK-S-1*	NAK-S-2	EQS EU [a]	EQS Georgian [b]
Total Organic Carbon	mg/l	1.2	<0.5	<0.5	1.7	0.84	---	---
Metals								
Aluminium	µg/l	<50	<50	<50	<50	<50	200	---
Antimony	µg/l	<2.0	<2.0	<2.0	<2.0	<2.0	5	---
Arsenic	µg/l	**26**	**24**	<5	**30**	<5	10	100
Beryllium	µg/l	180	140	<15	63	<15	---	---
Boron	µg/l	**7,700**	**2,600**	<50	**10,000**	<50	1	500
Cadmium	µg/l	0.21	<0.2	<0.2	0.56	<0.2	5.0	3.0
Calcium	meq/l	16	7	1	12	1	---	---
Chromium	µg/l	<1	<1	<1	<1	<1	50	---
Copper	µg/l	<0.2	<0.2	<0.2	<0.2	<0.2	2.0	2,000
Mercury	µg/l	<0.05	<0.05	<0.05	<0.05	<0.05	1.0	6.0
Lead	µg/l	2.9	3.8	<2	5.1	<2.0	10	10
Magnesium	meq/l	5.8	4.2	0.85	4.3	0.28	50	---
Manganese	µg/l	1,700	6,900	<10	1,100	<10	---	---
Molybnium	µg/l	<2	<2	<2	<2	<2	---	---
Nickel	µg/l<	6.2	<3	<3	18	<3	20	70
Selenium	µg/l	29	12	<3.9	29	<3.9	10	10
Iron	µg/l	2,200	64	<50	<50	<50	200	---
Zinc	µg/l	14	<10	15	17	<10	---	3,000
Total Hardness	meq/l	22	12	2.0	16	1.3	---	---
Inorganics								
Ammonium	mg/l	0.7	0.2	<0.2	<0.2	<0.2	0.5	---
Ammonium (N)	mgN/l	0.5	0.2	<0.15	<0.15	<0.15	---	---
Fluorides	µg/l	0.56	0.56	<0.2	<0.2	<0.2	---	---
Other Analysis								
Chlorides	mg/l	56	60	<3.0	58	<3.0	250	250
Nitrites	mg/l	<0.3	<0.3	<0.3	<0.3	<0.3	0.5	---
Nitrites (N)	mgN/l	<0.1	<0.1	<0.1	<0.1	<0.1	---	---
Nitrate	mg/l	<0.75	<0.75	2.0	<0.75	<0.75	50	---
Nitrate (N)	mgN/l	0.17	<0.17	0.44	<0.17	<0.17	---	---
Sulphates	mg/l	25	13	16	47	9.1	250	250
Alkalinity (as CaCO3)	mgCO3	1300	950	80	1400	43	---	---
Total Alkalinity	meq/l	26	19	1.6	28	0.9	---	---
Biological Oxygen Demand	mg/l	2.73	3.63	0.95	3.83	2.55	---	---
Chemical Oxygen Demand	mg/l	13.72	12.74	7.64	1.76	7.84	---	---
Total Coliforms in 300 ml	N°	**32**	**11**	**22**	**45**	**58**	---	---
Volatile organic halogens	µg/l	<5	<5	<5	<5	<5	10	---
Chlorobenzenes	µg/l	<0.005	<0.005	<0.005	<0.005	<0.005	0.1	---
Pesticides		ND	ND	ND	ND	ND	0.5	---

Source: JSC Nenskra Hydro

Notes:

meq/l: milliequivalent per litre

EQS: Environmental Quality Standard

Values in **Bold** text – indicate exceedance of EQS limit value

[a] : EU Directive 98/83/EC , 3rd November 1998 – on the quality of water intended for human consumption

[b] : Technical Regulations for Drinking Water approved by Order #349/n dated 17th December 2007

--- : not applicable, NB: Non Detected

* Mineral water spring

3.2.5 Interpretation of results and conclusions

3.2.5.1 River water quality

The key points regarding river water quality are as follows:

- There are no industrial activities and limited artisanal and agricultural activities upstream of the future reservoir on the Nenskra or the diversion weir on the Nakra Rivers;
- The waters were found to be typical of pristine streams in granite and gneiss rock type areas. Concentrations of organic carbon and nitrogen are very low and phosphorous below detection limits. Nutrient input from river water into the future reservoir is consequently very low and this is an important factor taken into consideration in the calculations for determining the risk of creating eutrophic conditions, and
- River water has normal pH for a mountain stream, low electrical conductivity and low concentrations of inorganics, which is typical of pristine mountain streams. Dissolved Oxygen is at saturation concentration for the temperature. No abnormal concentrations of metals were detected.

3.2.5.2 River water quality with respect to EU water framework directive

With respect to the EU Water Framework Directive 2000/60/EC of 23 October 2000, and in particular the requirement of Annex II - characterisation of surface water body types the salient points regarding the water quality of the Nenskra River are as follows:

The catchment area is of the high altitude (>800 metres), and comprises medium sized catchment area categories. The Nenskra River at the dam site is at an altitude of 1,300 metres and the catchment area encompasses 218 square kilometres.

Regarding the chemical status, although Georgia has not established physicochemical reference conditions it can be considered that the waters of the Nenskra and Nakra Rivers are of “high” chemical status. This is deduced because (i) the water quality survey has found that the water quality is typical of pristine mountain streams in granitic regions – based on criteria reported in *Water Quality Assessments – A Guide to Use of Biota, Sediments and Water in Environmental Monitoring* (Chapman (1996) which was published on behalf of UNEP and WHO, (ii) there is very little human pressure on the rivers, and (iii) no identified sources of pollution from the 33 priority substances listed in the Directive 2008/105/EC of 16 December 2008 regarding Environmental Quality Standards.

3.2.5.3 Spring and drinking water quality

Local people use both spring and river water as drinking water. The water is supplied to individual houses using flexible hoses – both buried and above ground. Local people reported that the water in the pipes does not freeze in winter, as the spring water temperature is constant all year round.

People interviewed were in general not aware of which members of the community are supplied by which water source. It appears that the choice is made at a household level and probably depends on which is the nearest source.

There is no municipal sewage collection network and consequently individual house are equipped with septic tanks and soak away systems to dispose of sewage. Also there are numerous farm animals moving freely along the river banks in the vicinity of villages.

The key characteristics of the spring and tap water are as follows:

- The water has a slightly higher electrical conductivity than that of the river water;

- Coliforms were detected in the water, which should render the water as unsuitable for human consumption, WHO recommends that coliforms should not be detected. The presence of coliforms may be due to the presence of farm animals freely roaming near the springs, and
- Metal concentrations do not exceed recommended WHO threshold values.

3.2.5.4 Mineral water quality

There are a limited number of mineral water springs in the valley. During the survey work, 3 sources of mineral water were brought to the attention of the water quality expert by local people. Water samples were taken, and in one case in-situ measurements were taken.

The key characteristics are as follows:

- The water has very high electrical conductivity (much higher than the river water and the spring water used as drinking water). High conductivity is due to high concentrations of calcium carbonate, boron and manganese;
- One spring (NEN-S-1, which is about 3 kilometres downstream from the dam) had particularly high iron concentrations.
- Arsenic concentrations are in the range of 0.024 to 0.030 mg/l, which is above World Health Organization (WHO) guideline values of 0.01 mg/l;
- Boron concentrations are between 2.6 and 10 mg/l. This is significantly higher than the WHO guideline value of 0.5 mg/l for drinking water. But concentrations of this order of magnitude are not unusual in mineral waters used for special health-related bathing, and the Caucasus is a renowned area for spar waters, Mestia is nearby and this is a renowned spar resort, and
- Coliforms were detected in the water, which should render the water as unsuitable for human consumption, WHO recommends that coliforms should not be detected. The presence of coliforms may be due to the presence of farm animals freely roaming near the springs.

Local people collect the mineral water for human consumption. However, the survey has found that this water is not suitable for human consumption because of the presence of coliforms, arsenic and high concentrations of boron.

4 Operation of the hydropower scheme

The assessment of hydrological, geomorphological and water quality impacts requires that the general principles of the operation of the hydropower scheme be considered. A detailed description of the Project is provided in Volume 2 – Project Definition and the key aspects necessary for this assessment are described in the following subsections.

4.1 Overview - operational and environmental constraints

The Nenskra reservoir operation is organised around managing a number of operational and environmental constraints. The inflow of water into the Nenskra reservoir comprises the total inflow of the Nenskra River and the diversion of the Nakra River via the Transfer Tunnel.

- JCS Nenskra Hydro has entered into a contractual agreement with JSC Electricity System Commercial Operator (ESCO) to provide during the months of December, January and February a monthly energy output that must reach at least 89.28 GWh. The Nenskra energy generation capacity is 280 MW and the 89.28 GWh represents an utilisation of 42 percent of the full energy generation capacity. During this period it is expected that energy generation will be provided on a continuous basis, with peak energy generation to provide for peak energy demands. Energy generation for peak energy demands results in changes in the rate of the flow of water which is turbined and discharged to the Nenskra River downstream of the powerhouse.
- For the months of March – November, there is a “take or pay” arrangement with ESCO. However, there are no energy production constraints for this period. Consequently, there could be intermittent energy generation resulting in intermittent turbining of water.
- An ecological flow of 0.85 m^3/s for the Nenskra River and an ecological flow of 1.2 m^3/s for the Nakra River must be provided all year. Additional information on ecological flow at the Nenskra dam is provided in section 4.5.1. The ecological flows were determined as part of the 2015 ESIA (Gamma) and the effectiveness of the ecological flow is assessed in Volume 4 of the Supplementary E&S Studies – Biodiversity Impact Assessment. This commitment is referred later in this report as:
    - [WAT 1] Mandatory Ecological flow downstream of Nenskra dam of 0.85 m^3/s
    - [WAT 2] Mandatory Ecological flow downstream of Nakra weir of 1.20 m^3/s.

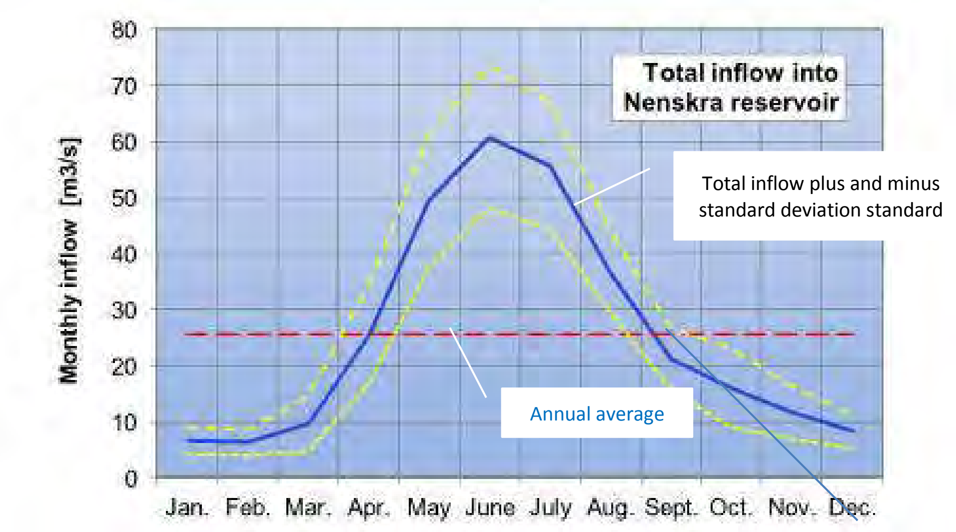
The months of December to February (which have a contractual power generation constraint) correspond to the months with the lowest reservoir inflow. Therefore, in order to ensure the energy output during these months the reservoir needs to be full at the end of November. During December to February power is generated mainly by the release of stored water from the reservoir and with a small contribution from the reservoir inflow. The flow of turbined water is managed so that the reservoir water level is at a minimum at the end of March, ensuring that a maximum amount of energy is produced during this period. During the rest of the year (April – October), which encompasses the months with the highest reservoir inflow rates – power is generated using reservoir inflow only. However, the flow of turbined water is managed so that the reservoir is progressively filled during this period and is full at the end of November.

4.2 Reservoir inflow

The mean monthly inflow of water into the reservoir is the combined flow of the Nenskra River and the deviated flow from the Nakra River via the transfer tunnel. The reservoir inflow from the Nakra River comprises the natural flow of the Nakra River at the diversion weir, less the ecological flow (1.2 m^3/s) maintained in the river downstream of the weir. The annual mean flow of water diverted from the Nakra to the Nenskra is 9.2 m^3/s and the tunnel is designed to allow for a maximum flow of 45.5 m^3/s. Consequently, during flood events in the Nakra, river flow in excess of 45.5m^3/s will overflow the diversion weir and continue in the Nakra River.

The Nakra end of the transfer tunnel is equipped with a gate system so that the tunnel can be closed if necessary (see section 4.8).

The monthly reservoir inflow (combined Nenskra and Nakra reservoir inflows) is presented in Figure 6 below. The figure illustrates that the lowest inflow is during the months of December to March, and the highest inflow is during the months of May, June and July.



Source: Stucky, 2016a

Figure 6 – Mean monthly reservoir inflow (1961 – 2014)

Table 14 – Mean monthly inflow and standard deviation at Nenskra dam site (m^3/s)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Flow	6.7	6.3	9.7	25.6	49.4	60.8	55.5	36.6	21.1	16.1	11.8	8.3	25.7
Stdev	2.4	2.4	4.9	8.7	11.7	12.8	11.3	7.1	5.5	7.0	4.6	3.0	6.78

Source: Stucky, 2016a

4.3 Reservoir outflow and water level

Outflow from the reservoir is controlled in order to respect the operational and environmental constraint. The resulting reservoir water level is provided in Figure 7 below.

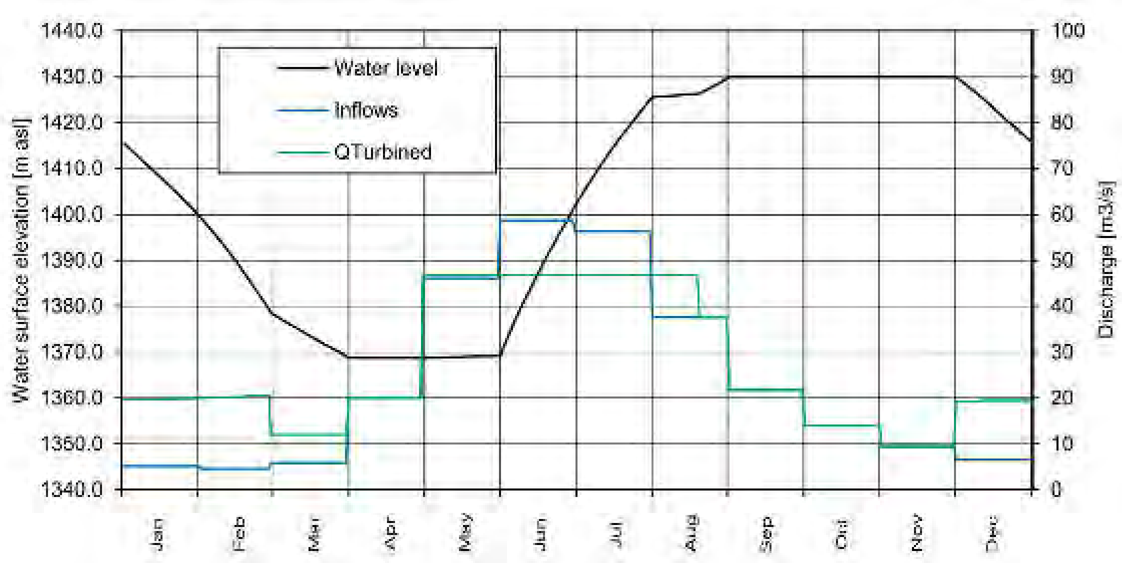


Figure 7 – Average monthly reservoir water level

4.4 Reservoir outflow at the powerhouse

The flow of turbined water is the main means of managing the reservoir volume and water level. The flow is controlled during the months of December to February so that the contractual amount of electricity of produced. The limiting factor is the volume of stored water in the reservoir – the reservoir must not be emptied too quickly or too slowly. During the period March – November, the flow is controlled so that the reservoir is full at the end of November. Having insufficient water in the reservoir at the end of November must be avoided.

There will be a continuous but variable outflow of reservoir water into the Nenskra River at the powerhouse. The annual mean flow is 25.7 m^3/s.

There may be hourly variations in flow rate of turbined water in order for the energy production to be adapted to hourly variations in demand. The general energy production is expected to be driven by the following:

- 22:00 – 06:00: low energy production during the night;
- 06:00 – 07:00: Night – day Transition hour;
- 07:00 – 17:00: High energy generation during the day, and
- 17:00 – 22:00: Maximum energy generation during the evening.

A simulation of the hourly variations in turbine flow rates on a monthly basis are presented in Figure 8 and maximum, minimum and average flow rates are presented in Table 15. The simulation is a hypothetical case and does not represent contractual agreements. The actual flow rates during operation can be expected to be similar, and will be driven by the schemes reaction to the electricity demand.

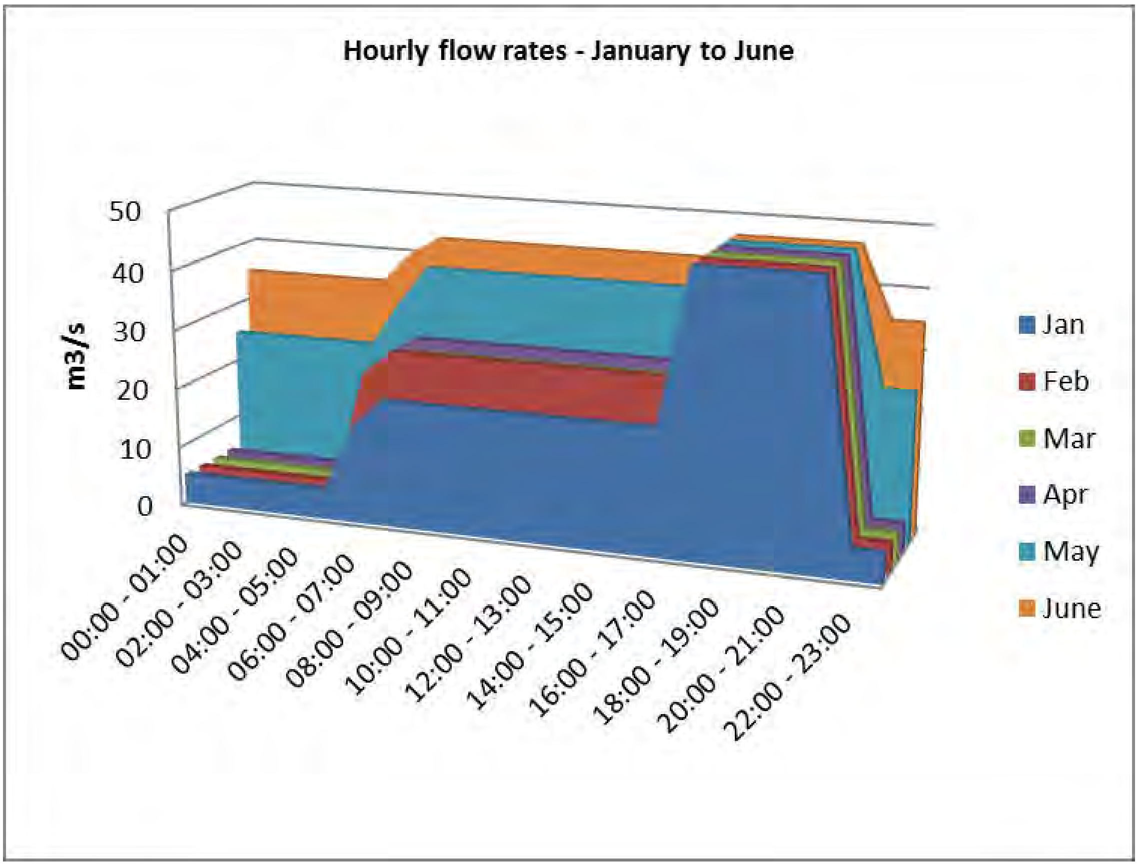
Table 15 – Mean monthly and hourly outflows at the Nenskra powerhouse (m^3/s)

Time	Hourly flow rate (m^3/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-1	5	5	5	5	25	35	25	10	5	5	--- [*]	5
1-2	5	5	5	5	25	35	25	10	5	5	--- [*]	5
2-3	5	5	5	5	25	35	25	10	5	5	--- [*]	5
3-4	5	5	5	5	25	35	25	10	5	5	--- [*]	5
4-5	5	5	5	5	25	35	25	10	5	5	--- [*]	5
5-6	5	5	5	5	25	35	25	10	5	5	--- [*]	5
6-7	16	24	20.5	25.2	32.5	40	29.5	23	9.5	9	3.5	8.5
7-8	21	28	27	28	39	43	33	31	17	9	9	20
8-9	21	28	27	28	39	43	33	31	17	9	9	20
9-10	21	28	27	28	39	43	33	31	17	9	9	20
10-11	21	28	27	28	39	43	33	31	17	9	9	20
11-12	21	28	27	28	39	43	33	31	17	9	9	20
12-13	21	28	27	28	39	43	33	31	17	9	9	20
13-14	21	28	27	28	39	43	33	31	17	9	9	20
14-15	21	28	27	28	39	43	33	31	17	9	9	20
15-16	21	28	27	28	39	43	33	31	17	9	9	20
16-17	21	28	27	28	39	43	33	31	17	9	9	20
17-18	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9
18-19	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9
19-20	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9
20-21	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9
21-22	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9
22-23	5	5	5	5	25	35	25	10	5	5	--- [*]	5
23-24	5	5	5	5	25	35	25	10	5	5	--- [*]	5
Average, maximum and minimum flow rates (m^3/s)												
Av.	20.9	24.1	23.5	24.2	35.7	41.0	33.1	27.0	18.9	14.0	10.3	20.1
Max.	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9
Min.	5	5	5	5	25	35	25	10	5	5	0	5

[*] November is the start of the period when the water level of the reservoir is progressively lowered and turbining of stored water needs to be carefully managed. In this simulation it is assumed that there will be no power generation during the night-time periods in November in order to best make use of the stored water. However, the values in this table are from a simulation and for indicative purposes only. There may well be turbining of water during the night-time in November.

General comment: maximum power generation is in the summer months when the reservoir inflows are highest.

Source: Stucky, 2016b



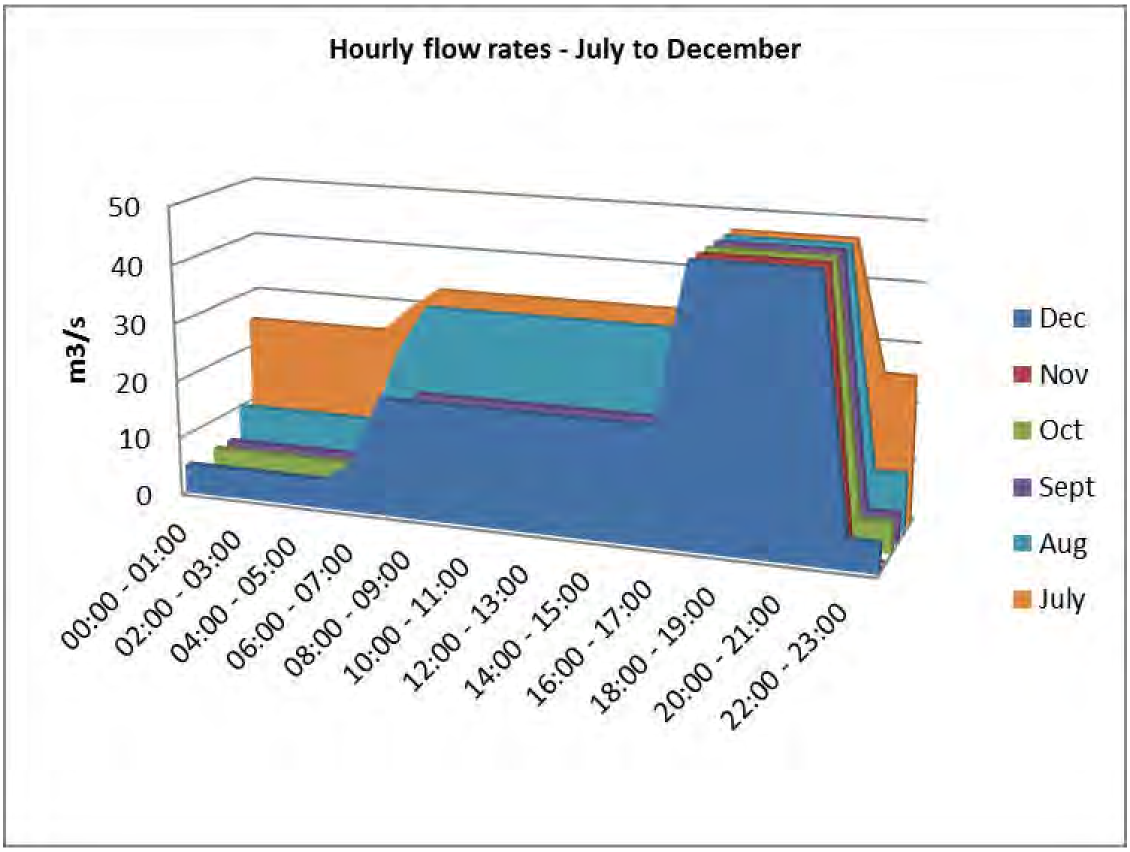


Figure 8 – Hourly flow rates for turbined waters on a monthly basis

Source: Stucky, 2016b

4.5 Reservoir outflow at the dam site

4.5.1 Ecological flow

An ecological flow of 0.85 m^3/s for the Nenskra River will be provided all year. The key points regarding the determination and effectiveness of the ecological flow are as follows:

- The 0.85 m^3/s was determined as part of the 2015 ESIA (Gamma) and validated by the Government of Georgia through the approval of the 2015 ESIA;
- The effectiveness of the ecological flow is assessed in Vol. 4 of the Supplementary E&S Studies – Biodiversity Impact Assessment. The assessment has shown that the ecological flow is not the critical factor with regard to maintaining ecological continuity and no net loss of biodiversity. The limiting factor is the physical presence of the dam, which acts as a barrier blocking access for fish to spawning areas that are upstream from the dam in the future reservoir area and further upstream;
- There are no spawning areas in the 2 kilometres immediately downstream from the Nenskra dam and probably no spawning areas will develop in this reach after the dam has been built as the gradient of the river is very steep. Consequently, it is not considered necessary to maintain a larger flow in this reach from a fish biodiversity perspective, and
- The adopted approach is to maintain ecological continuity downstream from the Nenskra River's confluence with the first tributary downstream from the dam – which is the Memuli - located at 2 kilometres from the dam. Downstream of the Memuli confluence there are areas that could become spawning areas as a result of the reduced flow.

The ecological flow is released from the dam's bottom outlet (technical description provided in Vol. 2 – Project Definition). The bottom outlet gates are usually closed and consequently the ecological flow will be discharged through a steel pipe bypassing the gates. The need for a backup pipe will be evaluated as part of the detailed design process. The flow rate through the pipe is dependent on the reservoir water level and therefore to ensure a continuous flow that is at least equivalent to the mandatory ecological flow the pipe is equipped with an automated flow control valve. The pipe dimeter will be sized to ensure that the flow discharged when the reservoir is a minimum operating level is equal or greater than the mandatory ecological flow. This commitment is referred to later in this report as:

- [WAT 3] The diameter of the Environmental Flow pipe is defined to confirm its capacity at minimum operating level and the option to use two pipes to minimise the risk of gate valve malfunction will be assessed as part of the detailed design process.

4.5.2 Outflow during normal operation

Ecological flow during normal operation for a "typical" year in terms of precipitation, the outflow immediately downstream of the dam comprises only the ecological flow with a flow rate of 0.85 m^3/s. The flow is continuous throughout the year. The ecological flow is discharged through a bypass pipe installed in the bottom outlet structure (see Vol. 2 Project Definition). The ecological flow pipe is equipped with an automated flow control valve to ensure that the mandatory flow rate is discharged.

The dam is equipped with a fixed weir type spillway with the weir crest at the maximum operating level. However, because of the volume of the reservoir and the capacity of the turbines, it is not expected that there will be spillage of reservoir water via this spillway during a typical year. Nevertheless during a "wet" year – which is a year with runoff approximately 10 percent higher than the average – and which is forecast to occur 2 years out of 10, it is expected that there could be intermittent spillage of reservoir water when the reservoir is at maximum operating level. This will cause a release of water into the Nenskra River downstream of the dam. Most of the spillage (90 percent) is expected to occur during the month of August, though some more limited spillage could occur in September or October.

The flow rate is estimated to be in the order of 10 to 20 m^3/s and for an approximate maximum duration of 2 to 4 hours per day.

The reasoning for the estimation of duration and flow rate of spillage is as follows:

- Spillage can only occur when the reservoir water level is at the level of the fixed weir – which could be during the months of August, September, October and November;
- Spillage can only occur when reservoir inflow is greater than discharge of turbined waters;
- The spillage rate would correspond to the difference between inflow and turbined flow and this is estimated to be between 10 to 20 m^3/s.

To minimise the amount of spilled reservoir water, the Nakra transfer tunnel inlet is equipped with a gate and when the Nenskra reservoir is spilling the gate will be closed to reduce reservoir inflow and stop or at least minimise spillage (see section 4.8). This commitment is referred to later in this report as:

- [WAT 4] Transfer of water from the Nakra River will be suspended to the extent possible in order to avoid spillage at the Nenskra dam.

During a normal year, reservoir spillage could occur when turbines are not in operation, for example in the case of a technical problem or if there is no power demand. However, this situation is expected to be unusual and infrequent. In addition, the turbines at the powerhouse are equipped with injectors and deflectors - devices that are an integral part of the turbines - and which allow inflowing water to bypass the power generation part of the turbine when the turbine is shutdown. This allows the passage and discharge of reservoir water even when the turbines are not in operation. This feature will allow reservoir water spillage via the spillway to be minimised. The discharge rate from the injectors and deflectors will nevertheless be below the maximum discharge capacity of the turbines.

It is to be noted that as a measure of precaution the spillway is designed to evacuate safely the PMF which has been established for the case that the Nakra diversion is operational and power turbines are not in operation.

4.5.3 Outflow during flood events

During a flood event, the Nenskra inflow flood water will first be contained in the reservoir - if it is not full – and once the reservoir is full, the flood water will be evacuated via the spillway. During a flood event, the diversion of the Nakra waters to the Nenskra reservoir will be stopped by the closing of a gate at the inlet to the Nakra transfer tunnel.

The discharge from the spillway during a flood event will depend not only on the reservoir inflow, but also the rate of turbining at the powerhouse. The maximum capacity of the turbines is 46.9 m^3/s, consequently, in the case that turbines are in operation at full capacity during a flood event the discharge from the spillway will be that of the natural conditions less the turbining rate. However, for safety reasons the spillway has been designed to be able to safely evacuate a flow equivalent to the sum of the Nenskra PMF (1,100 m^3/s) and the maximum Nakra diversion inflow (46 m^3/s) and so is sized to evacuate 1,146 m3/s. The peak discharges and return period from the Nenskra dam spillway for flood events for the case that the turbines are stopped but Nenskra transfer tunnel gate is closed are provided in Table 16.

Table 16 – Peak discharges for flood events

Return period (years)	Spillway discharge*
PMF	1,100
10,000	300
1,000	246
100	193
25	160
10	138
5	121
2.33	99

* Calculated for the case with inflow from the Nakra and with the power generation turbines stopped. For the case of the PMF the total inflow is 1,146 m^3/s but the reservoir has an attenuation effect and the overflow at the spillway is 1,100 m^3/s.

4.6 Management of sediment in the Nenskra reservoir

The estimation of the quantity of sediment that could accumulate in the Nenskra reservoir is based on sediment runoff data collected from the Lakhami gauging station during the period 1956-1989 and for a catchment of 469 square kilometres and it is assumed (as a worst case scenario[2]) that the sediment load in the Nakra waters is transferred to the Nenskra reservoir.

According to the calculations the input of solid material to the Nenskra reservoir will be 0.06 million cubic metres per year. The elevation of the bottom outlet gate is at 1,316 metres and the reservoir volume at that level is approximately 1.58 million cubic metres. With a sediment inflow rate of 0.185 million cubic metres per year, the sediment accumulation could reach the level of the bottom outlet after approximately 26 years of operation.

The sediment input calculations assumed that there is little input from landslides and debris-flow in the reservoir. However, it is considered that landslide and mudflow/debris flow events could occur in the reservoir area and which could result in higher sediment input loads into the reservoir than predicted by the model.

It can therefore be assumed that there could eventually - after a number of years – be a need to vent the sediment that has accumulated in the reservoir in order to avoid blocking the bottom outlet gate. The bottom outlet must be maintained available as it has an important dam safety function and is a critical component for a sustainable scheme – as the ecological flow passes through the bottom outlet. The sediment can expected to be vented by emptying completely the reservoir at a time of year when flood events can be expected, and to open the bottom outlet gate at the start of a flood event in the order that the flood vents the sediment out of the reservoir.

To reflect the importance of the operability and functioning of the bottom outlet, the Project Company has made the following commitment:

The Project Company will ensure that a robust detailed study, in alignment with best international practice, will be undertaken to assess the risk of the blockage of the bottom outlet from sediment. The assessment will take into account inflow of sediment from the

[2] Measures will be in place to minimise as far as possible the risk of bedload, unsuspended sediment being transferred through the Nakra transfer tunnel.

catchment, and sediment from landslide and debris flow events (including from the reservoir slopes and taking into account the locations of existing debris and avalanche chutes, as discussed in Vol. 6). Climate change and seismic activity – including Reservoir Triggered Seismic events - will be taken into account. The Project Company will ensure that the design of the bottom outlet is such that availability of this critical safety feature is ensured at all times. It should be noted that the diameter of the bottom outlet conduit is 4 metres. Operating procedures and inspection and maintenance programmes will be developed to ensure the availability and efficient operability of the bottom outlet – including the continuous ecological flow system which is integrated into the bottom outlet. The study will be reviewed by the Lenders and IPoE before reservoir impoundment.

This commitment is referred to as:

- [WAT 5] Availability and safety and ecological flow functions of the bottom outlet are ensured through careful siting, design, operational procedures and inspection, control & maintenance programmes.

4.7 Nenskra River flow during dam construction and reservoir filling

The detailed methods of controlling the Nenskra River flow during dam construction will be defined during the detailed design and are unavailable at the time of writing. However, a high level overview is provided here, and additional information provided in Vol. 2 Project Definition.

A rockfill coffer dam will be constructed upstream of the Nenskra main dam site to divert the Nenskra River during construction of the main dam. The coffer dam is constructed with culverts through the structure and through which will flow the Nenskra river waters. One of the culverts will be designed so that the minimum flow through the culvert for the lowest upstream water level will be at least equivalent to the ecological flow.

When the construction of the main dam is ready to start, mechanical shovels are used to partly block the culverts with rock, but leaving the ecological flow culvert open. The head pond upstream of the coffer dam will consequently to start filling and eventually to reach the level of the outlet intake which is located in the reservoir banks (not the dam structure). The open culverts will at the same time allow river water to continue flowing, with a flow rate that is below the normal river flow rate but equivalent or superior to the ecological flow.

The time for the water level of the head pond to reach the outlet intake will depend on the time of year that filling takes place, however it is expected to take only a few hours. When the head pond water level reaches the outlet inlet and the Nenskra river flow has been completely diverted, the culverts are completely closed.

When the construction of the main dam structure has reached an elevation of 1,375 metres, and the construction of the bottom outlet has been completed. The coffer dam culverts are reopened, and the head pond drained and the stored water released downstream through the dam bottom outlet and ecological flow control system.

The first reservoir filling operation is planned in two phases as described below. The project will endeavour to commence power generation during the reservoir filling. Detailed descriptions of the reservoir filling and early energy generation are described in Vol. 2 Project Definition.

- Phase 1. During the dam construction period, the reservoir will be gradually filled up, up to a maximum elevation of 1,370 metres asl. The rise of the water level in the reservoir will be controlled by means of the bottom outlet in order to avoid subjecting the dam structure to rapid changes in hydraulic load.

- Phase 2: When the dam construction is completed, the reservoir impoundment will proceed further up to its standard operation level (1,430 metres asl). End of 2020, the transfer tunnel between the Nakra and the Nenskra valleys will be completed and the Nakra River will begin to be diverted into the Nenskra reservoir.

During the whole dam construction and reservoir filling process, the mandatory ecological flow will be maintained. The EPC Contractor is contractually required to provide a method statement with respect to how the ecological flow will be maintained during construction and this will be verified by the Project prior to construction. During the construction works the Owners Engineer supervision team will be present to check that the method for maintaining the ecological flow is indeed implemented. Downstream from the dam will be installed a simple structure or devise for the purpose of community participatory monitoring of the ecological flow - and which could include a webcam. This structure/system will be installed before any diversion of the Nenskra River is undertaken.

This commitment is referred later in this report as:

- [WAT 6] The Nenskra dam and coffer dam construction methods are adapted to ensure that the minimum ecological flow will be maintained at all times during construction with real-time monitoring and disclosure of the ecological flow on a website.

The Nenskra reservoir volume is 176 million cubic metres at the maximum operating level. The time necessary to fill the reservoir in each phase is 3 -7 months depending on the month of the start of filling, and considering the mean monthly hydrology. The time could be longer in the case of a dry year. It could also be longer if for structural reasons it is necessary to fill the reservoir at a lower rate to avoid rapid changes in hydraulic loading of the dam structure. The rate of the reservoir filling is controlled using the bottom outlet. Consequently during reservoir filling the reservoir outflow comprises the ecological flow (0.85 m^3/s) and possibly an additional flow from the bottom outlet not defined at this stage but which will be less than the river flow under natural conditions.

4.8 Design and operation of the Nakra River diversion

4.8.1 Design concept and features

The concept design of the Nakra weir and transfer tunnel inlet are provided in Vol. 2 Project definition. However, the main features and functions are as follows:

- The weir is situated immediately downstream of the transfer tunnel inlet creating a small upstream head pond;
- The weir is designed to divert the flow of the Nakra River into the transfer tunnel which conveys the river water to the Nenskra reservoir. The tunnel is designed for an average flow rate of water of 9.2 m^3/s and a maximum flow rate of 45.5 m^3/s. During normal operation the risk of bedload sediment being transported into the transfer tunnel is considered minimal. However, without management it is assessed there would be potential for bedload sediment to be entrained in the transfer tunnel during flood events. This risk will be addressed through design; the weir and transfer tunnel will be designed with features for sediment flushing and to prevent sediment being transported into the transfer tunnel (and conveyed to the Nenskra reservoir) during flood events.
- The weir is designed to allow the discharge of an ecological flow via a natural fish pass structure in order to ensure that the ecological functionality of the Nakra River is

maintained. The continuous flow in the fish pass is controlled by a small weir upstream of the pass which maintains a minimum flow rate of 1.2 m^3/s. The weir is also equipped with a bypass pipe equipped with a manual valve so that if necessary the ecological flow can be increased.

- The weir is designed to allow safe overtopping, so that during flood events when the upstream inflow is greater than 45.5 m^3/s (capacity of the transfer tunnel) that the flow in excess of 45.5 m^3/s can be safely released into the Nakra river downstream of the weir.
- The transfer tunnel inlet is equipped with a remotely operated gate which is operated to prevent spillage of the Nenskra reservoir (see 4.5.2 and [WAT 4]). The situations when there will be a need to close the transfer tunnel inlet gate are as follows:
  - During a normal operational situation when the Nenskra reservoir is full, but water is spilling from the reservoir via the spillway, this situation may occur during a wet year when the reservoir is full during the summer months;
  - During a flood situation when the Nenskra reservoir is full and the reservoir is spilling. The closing of the Nakra transfer tunnel inlet gate will prevent the flood flows in the Nenskra valley being of greater magnitude than those of the situation without the Project, and
  - When tunnel inspection and maintenance needs to be carried out.

- The weir is equipped with two large gates to enable the sediment transport function of the Nakra River to be maintained by periodically re-establishing the natural flow of the Nakra River (i.e. re-establishing the conditions without the Project) during flood events. This can be done by opening the weir gates and closing the transfer tunnel inlet gate. The purpose of this operation flush is twofold; (i) to flush downstream sediment that has accumulated in the head pond, and (ii) flush downstream sediment that has accumulated in the Nakra riverbed downstream from the weir, which is an impact caused by the Project (see section 6.2.1.2).
- The gates are powered by a dedicated 30 kVA diesel-fuelled power generator (with a back-up) the generator will be installed at the weir location. The weir will be permanently manned and the operators will be in communication with the operators at the Nenskra dam by telephone, in addition both valleys are covered by the mobile phone network.

Detailed operating procedures for the Nakra weir will be prepared as the Project moves forward. The procedures will include the definition of thresholds for determining when the Nakra transfer tunnel inlet gate is to be closed for sediment flushing reasons – and to ensure that the gate is not maintained open to maintain energy production when for safety reasons it should be closed. This commitment is referred to later in the report as:

- [WAT 7] Preparation and implementation of detailed procedures for the operation of the Nakra weir and the Nakra transfer tunnel inlet gate.

4.8.2 Detailed design and operation

A. Ecological flow and trapped sediment management

The Nakra intake detailed design will ensure that the ecological continuity of the river is maintained, that the ecological flow is guaranteed, that the sediment trapped upstream of the weir is efficiently and regularly flushed downstream of the weir and that the sediment inflow into the transfer tunnel is prevented. Efficient downstream transfer of sediment trapped in the head pond will be ensured through detailed design and the development of operating procedures, inspection and control programmes and maintenance programmes. The need for mechanical removal of trapped sediment both upstream and immediately downstream of the weir will be avoided as far as is technically practicable, as will the need for land acquisition for the disposal of sediments removed from the river.

During the weir construction, head pond filling and weir operation, the mandatory ecological flow will be maintained. The EPC Contractor is contractually required to provide a method statement with respect to how the ecological flow will be maintained during construction and this will be verified by the Project prior to construction.

The work plan for the construction of the diversion weir will ensure that there will be no interruption of the flow of the Nakra River during the construction of the weir. The plan is expect to include the construction of a lateral coffer dam, which will extend from one of the banks of the river towards the centre of the river in a downstream direction - creating a dry area where part of the weir will be constructed – but without damming the river. This process will then be repeated from the other bank. The weir is equipped with a bypass conduit - with an open/close valve - which is sized to allow the mandatary ecological flow. Towards the end of the weir construction, the bypass will be opened to allow the ecological flow to be discharged, and then the coffer dam will be closed damming the river. The head pond will then fill reaching a level whereas the ecological flow will be discharged via the fish pass. The ecological flow bypass can then be closed.

During the construction works the Owner's Engineer's supervision team will be present to check that the method for maintaining the ecological flow is indeed implemented. Downstream from the weir will be installed a simple structure or device for the purpose of community participatory monitoring of the ecological flow - and which could include a webcam. This structure/system will be installed at the start of the Nakra construction works. This commitment is referred to as:

- [WAT 8] Ensure that sediment trapped upstream of the Nakra Intake is flushed downstream and that the ecological continuity of the river is maintained at all times during construction and operation with real-time monitoring and disclosure of the ecological flow on a website.

B. Maintaining the Nakra sediment transport function

In its current condition – without the proposed river diversion - the Nakra valley is subject to occasional landslide events in lateral valleys, causing mudflows that can temporarily block the Nakra River and represent a risk of flooding properties. The Project will reduce flow rate of the Nakra River causing a significant reduction of the Nakra sediment transport capacity, which may reduce the river's capacity to flush away such periodic natural blockages. To address this issue, JSCNH committed to ensure sediment that accumulates in the riverbed downstream from the weir will be flushed away by periodically opening the diversion weir gates and closing the transfer tunnel inlet gates. This operation will be normally during flood events when the Nenskra reservoir is full and overflowing. However, if a mudflow/debris flow event occurs in the Nakra valley and requiring the reinstatement of the Nakra's natural flow the Nakra transfer tunnel gate will be closed even if the Nenskra reservoir is not at full supply level.

The most effective method for controlling accumulated sediment by re-establishing periodically the natural flow of the Nakra River will be determined by a specific study. The scope of the study will include improving the current understanding of the baseline sediment situation, establishing recommendations for (i) sediment flushing flow rates, frequency and duration, (ii) sediment accumulation monitoring and (iii) evaluation of the need for and concept of river maintenance works and implementation of the solution in liaison with the local community – including the realignment of the Nakra near the confluence with the Lekverari. The need for mechanical removal of sediment will be avoided as far is technically practicable and mechanical removal will be only performed when no other alternative is available. Any such sediment removal works will be performed in alignment with standard practice in other EU countries and will not result in adverse sediment transport. This commitment is referred to later in the report as:

- [WAT 9] Maintain the sediment transport function of the Nakra River.

C. Nenskra valley flood control

The diversion of the Nakra River flow to the Nenskra reservoir will cause an increase in the annual average flow in the Nenskra River downstream from the powerhouse and this is controlled through reservoir management and the turbining at the powerhouse. However, during flood events, when the Nenskra reservoir is full and overflowing, the flow in the Nenskra downstream from the dam will be higher than the natural conditions – i.e. compared to the situation without the proposed Project - this is because of the additional incremental flow from the Nakra. The diversion of the Nakra River therefore results in an increased risk of flooding in the Nenskra valley. To control the increased risk, the Project Company has made a commitment that the Nakra transfer tunnel will be equipped with a remotely operated gate and that during flood events when the Nenskra reservoir is overflowing the Nakra transfer tunnel inlet gate will be closed. This commitment is referred to later in the report as:

- [WAT 10] Mitigate the risk of floods in the Nenskra valley through control of the Nakra River diversion.

5 Impact on downstream hydrology

This section presents the assessment of the impacts of the Project's hydraulic structures on the hydrology of the Nenskra and Nakra rivers.

It should be noted that it is only the presence of the hydraulic structures that are expected to affect river hydrology.

Water abstraction will be carried out to supply the construction and operation activities:

- During construction, 0.034 m^3/s taken from Nenskra River, for drinking water (camps) and industrial water, which is negligible compared to the average monthly flow in January, February and March which is the order of 5 m^3/s at dam site.
- During reservoir filling, 0.016 m^3/s is taken from the Nenskra River, for drinking water (camps) which is negligible compared to ecological flow of 0.85 m^3/s, i.e. less than 2 percent.
- During operation, 0.0007 m^3/s is taken from Nenskra River mainly for drinking water (operators' village), which is negligible compared to ecological flow 0.85 m^3/s, i.e. less than 0.1 percent.

These figures are conservative as most of the water will return to the natural environment after treatment.

There is no plan to abstract water from tributaries and in the event that water does need to be abstracted, this will be subject to environmental review prior to any abstraction.

This commitment is referred to later in this report as:

- [WAT 11] Any water abstraction from tributaries of the Nenskra or Nakra Rivers subject to prior environmental review.

5.1 Impacts on hydrology downstream of the Nenskra reservoir

5.1.1 Normal operation

Table 17 presents average monthly flow rates for the situation with the dam and Table 18 presents the difference in monthly flow rates between with and without the dam. Monthly flow rates are also illustrated on Map 5-1.

5.1.1.1 Between dam and powerhouse

A. Typical year

The Nenskra River is affected by a reduced river flow due to the storage of the Nenskra River water in the reservoir and the diversion of the Nakra River to the Nenskra reservoir. At each strategic location downstream from the dam, the average monthly discharge has been calculated and is the sum of the ecological flow and the natural runoff at that location.

The differences in flow rates between the situation with and without the dam are presented in Table 18 and illustrated on Map 5-1.

The results illustrate that the monthly flow rates are lowered as a result of the Project at every location and for every month of year. During a typical year, no spillage of reservoir water via the spillway is expected (see Section 4.5) – and no sudden intermittent variations in flow rate are expected. A typical year occurs 8 years out of every 10 years.

B. Wet year

During a wet year – which occurs 2 years out of every 10 years – the ecological flow from the dam-reservoir will remain the same as for a normal year, and the flow from the various tributaries will be slightly higher in the same proportions as for the Nenskra inflow presented in Figure 6 on page 36.

The changes in flow rate of the Nenskra for a wet year will therefore be in the same order of magnitude as for a typical year and consequently the computation of the changes in flow rate are not included in this report. However, during a wet year the Nenskra will be affected by the spillage of reservoir water via the dam spillway during the month of August (see Section 4.5).

It is estimated that the spillage will be in the order of 10 – 20 m^3/s for a duration of about 2 to 4 hours – and potentially occurring every day when the reservoir is full and most probably in August, but also possibly in September. The magnitude and duration is spillage is influenced by the hourly inflow – which is predominantly glacial melt water – and the rate of turbining. The reservoir operation will endeavour to minimise reservoir spillage.

In the event of such spillage, there will be a sudden and short duration increase in the Nenskra flow downstream from the dam as illustrated in the graphs provided in Map 5-2. However, the maximum flow rates with spillage at the different strategic locations are less than average monthly flow for July (natural conditions without the dam), which is the month with the highest flow.

Consequently, it can be deduced that the increased flow rate from spillage will not cause downstream flooding and the flow rate will be similar to that of the natural conditions during the months of April and September.

Nevertheless, such sudden and short duration flows may represent a risk of people and their livestock who may be in the riverbed or on the banks. This risk is managed through the Emergency Preparedness Plan which is described in Vol. 6 Natural Hazards and Dam Safety. Mitigation measures are also described in section 5.1.1.3D.

Table 17 – Nenskra average monthly river flow rates with dam – typical year

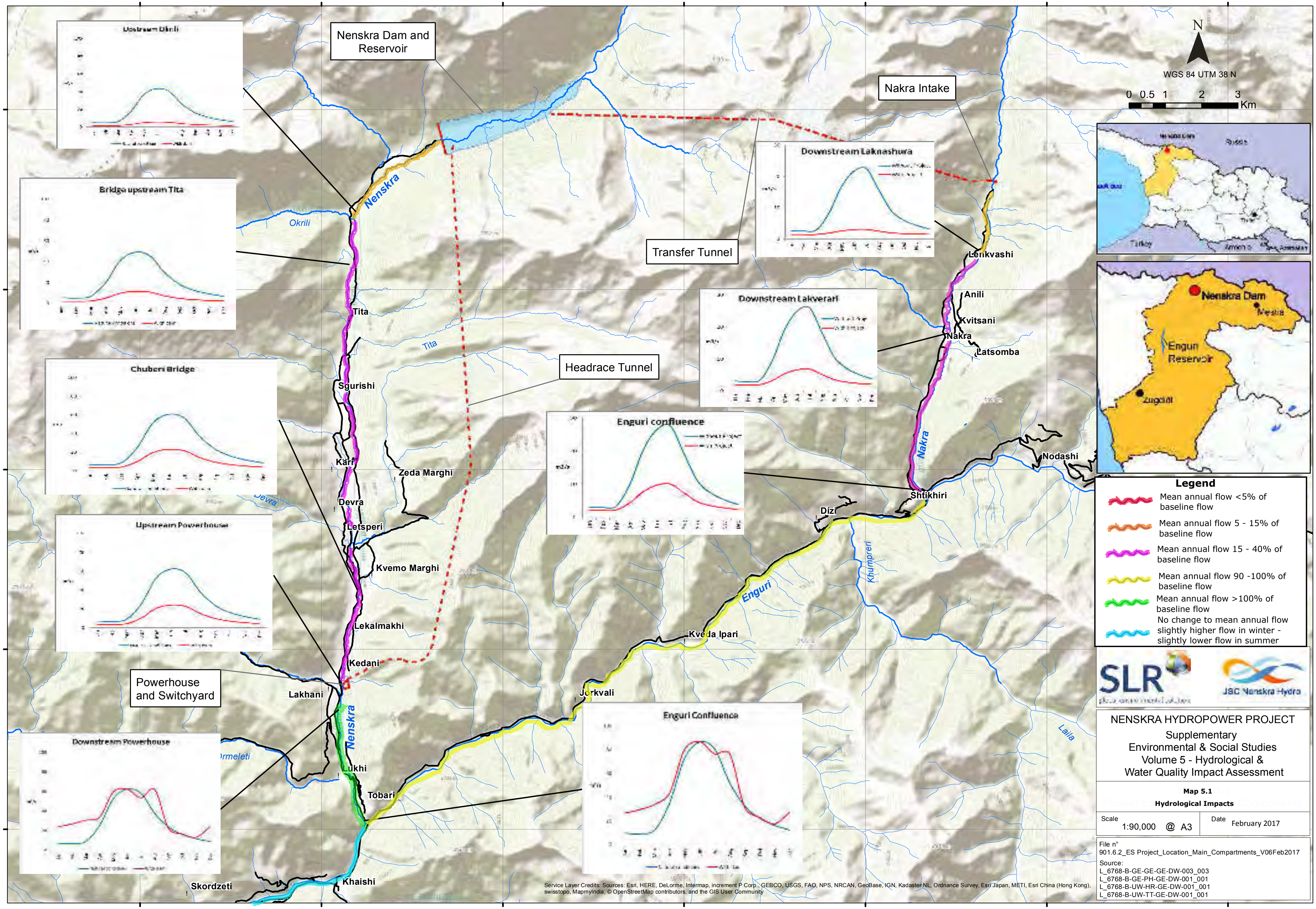
Location on Map 2.1	Location in the valley	Catchment area parameters			Annual discharge		Mean monthly discharge (m^3/s)											
		Approx. Distance from Enguri confluence	Area excluding Nenskra dam catchment area	Mean Elevation	Unit annual discharge [a]	Mean Annual Discharge [a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		km	km^2	m asl	l/s/km²	m^3/s												
	Turbine discharge (m^3/s)						20.4	23.5	26.3	23.4	39.1	38.2	31.1	46.9	12.6	9.8	7.8	19.8
	Ecological flow (m^3/s)						0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
NE0	Enguri Confluence	0	392	1,945	52	20.4	26.6	29.5	34.0	43.6	80.3	86.9	76.5	76.6	31.5	22.9	17.7	27.4
NE1	Main Bridge	1.4	243	1,978	52	12.6	24.5	27.5	31.4	36.2	64.9	68.6	59.5	65.6	24.6	18.2	14.3	24.8
NE2	Downstream Power Station	4.3	180	2,024	55	9.9	23.8	26.9	30.5	33.6	59.5	62.3	53.6	61.8	22.2	16.6	13.1	23.9
NE2	Upstream Power Station	4.3	180	2,024	55	9.9	3.5	3.3	4.2	10.3	20.5	24.1	22.6	14.9	9.7	6.8	5.2	4.2
NE3	Chuberi Main Bridge	7.2	169	2,076	56	9.5	3.3	3.2	4.0	9.9	19.6	23.0	21.6	14.2	9.3	6.6	5.0	4.0
NE4a	Downstream confluence with Devra	9.3	134	2,146	58	7.8	2.9	2.8	3.5	8.2	16.2	19.0	17.8	11.8	7.7	5.5	4.3	3.5
NE4b	Upstream confluence with Devra	9.4	120	2,169	59	7.1	2.7	2.6	3.2	7.6	14.9	17.5	16.3	10.9	7.1	5.1	4.0	3.2
NE5	Footbridge near main left bank spring	12.6	103	2,233	62	6.4	2.5	2.4	3.0	6.9	13.4	15.8	14.8	9.8	6.5	4.7	3.7	3.0
NE6	Small Bridge	14.3	72	2,266	63	4.6	2.0	2.0	2.4	5.2	9.9	11.5	10.8	7.3	4.9	3.6	2.9	2.4
NE7	Main Bridge Upstream Tita	17.5	61	2,380	66	4.0	1.9	1.9	2.2	4.7	8.8	10.2	9.6	6.5	4.4	3.3	2.6	2.2
NE8a	Downstream Okrili tributary confluence	18.6	58	2,403	67.5	3.9	1.9	1.8	2.2	4.6	8.6	10.1	9.5	6.4	4.3	3.2	2.6	2.2
NE8b	Upstream Okrili tributary confluence	18.8	30	2,340	66	2.0	1.4	1.4	1.5	2.8	4.8	5.6	5.2	3.7	2.6	2.1	1.7	1.5
	Dam site (including Stream n°2)	21.7	0		70	0.0	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85

[a]: Run-off per hectare reported in literature for the Caucasus Mountains – Trans-Caucasian Hydro-Meteorological Research Institute, 1967

Table 18 – Changes in average monthly flow rates for Nenskra River caused by dam – Typical year

Location on Map 2.1	Location in the valley	Catchment area parameters: Approx. Distance from Enguri confluence (km)	Area without Nenskra dam catchment area (km²)	Mean Elevation (m asl)	Annual discharge: Unit annual discharge [a] (l/s/km²)	Mean Annual Discharge [a] (m^3/s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
							Mean monthly discharge (m^3/s)											
	Turbine discharge (m^3/s)						20.4	23.5	26.3	23.4	39.1	38.2	31.1	46.9	12.6	9.8	7.8	19.8
	Sanitary flow (m^3/s)						0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
NE0	Enguri Confluence	0	392	1,945	52	20.4	16.9	20.3	21.7	8.5	7.3	0.4	-4.1	24.5	-1.2	0.6	1.4	15.1
NE1	Main Bridge	1.4	243	1,978	52	12.6	16.7	20.1	21.4	7.9	6.0	-1.1	-5.6	23.5	-1.8	0.2	1.1	14.9
NE2	Downstream Power Station	4.3	180	2,024	55	9.9	16.8	20.2	21.6	8.4	7.0	0.0	-4.5	24.2	-1.4	0.5	1.3	15.0
NE2	Upstream Power Station	4.3	180	2,024	55	9.9	-3.5	-3.3	-4.7	-15.0	-32.1	-38.2	-35.6	-22.7	-13.9	-9.2	-6.5	-4.7
NE3	Chuberi Main Bridge	7.2	169	2,076	56	9.5	-3.5	-3.2	-4.6	-14.7	-31.5	-37.5	-34.9	-22.3	-13.7	-9.0	-6.4	-4.6
NE4a	Downstream Devra confluence	9.3	134	2,146	58	7.8	-3.5	-3.3	-4.7	-14.8	-31.7	-37.7	-35.1	-22.4	-13.7	-9.1	-6.4	-4.7
NE4b	Upstream Devra confluence	9.4	120	2,169	59	7.1	-3.4	-3.2	-4.6	-14.5	-31.2	-37.1	-34.6	-22.0	-13.5	-8.9	-6.3	-4.6
NE5	Footbridge near main left bank spring	12.6	103	2,233	62	6.4	-3.5	-3.2	-4.6	-14.7	-31.5	-37.5	-35.0	-22.3	-13.7	-9.1	-6.4	-4.6
NE6	Small Bridge	14.3	72	2,266	63	4.6	-3.5	-3.2	-4.6	-14.7	-31.5	-37.5	-34.9	-22.3	-13.7	-9.0	-6.4	-4.6
NE7	Main Bridge Upstream Tita	17.5	61	2,380	66	4.0	-3.5	-3.2	-4.6	-14.7	-31.5	-37.5	-34.9	-22.3	-13.7	-9.0	-6.4	-4.6
NE8a	Downstream Okrili tributary confluence	18.6	58	2,403	67.5	3.9	-3.4	-3.2	-4.6	-14.6	-31.3	-37.3	-34.7	-22.1	-13.6	-9.0	-6.3	-4.6
NE8b	Upstream Okrili tributary confluence	18.8	30	2,340	66	2.0	-3.5	-3.3	-4.7	-14.8	-31.6	-37.7	-35.1	-22.4	-13.7	-9.1	-6.4	-4.7
	Dam downstream confluence Stream 2	21.7	4	2,483	70	0.2	-3.5	-3.3	-4.7	-14.8	-31.7	-37.7	-35.1	-22.4	-13.7	-9.1	-6.4	-4.7

[a]: Run-off per hectare reported in literature for the Caucasus Mountains – Trans-Caucasian Hydro-Meteorological Research Institute, 1967



Nenskra Dam and Reservoir
Nakra Intake
Transfer Tunnel
Headrace Tunnel
Powerhouse and Switchyard
Upstream Okrili
Bridge upstream Tita
Chuberi Bridge
Upstream Powerhouse
Downstream Powerhouse
Downstream Laknashura
Downstream Lakverari
Enguri confluence
Enguri Confluence
Nenskra
Nakra
Enguri
Okrili
Tita
Devra
Khumpreri
Laila
Tita
Sgurishi
Kari
Zeda Marghi
Devra
Letsperi
Kvemo Marghi
Lekalmakhi
Kedani
Lakhani
Lukhi
Tobari
Khaishi
Skordzeti
Lenkvashi
Anili
Kvitsani
Nakra
Latsomba
Nodashi
Shtikhiri
Dizi
Kveda Ipari
Jorkvali
N
WGS 84 UTM 38 N
0 0.5 1 2 3 Km
Russia
Turkey
Nenskra Dam
Mestia
Enguri Reservoir
Zugdidi
Legend
Mean annual flow <5% of baseline flow
Mean annual flow 5 - 15% of baseline flow
Mean annual flow 15 - 40% of baseline flow
Mean annual flow 90 -100% of baseline flow
Mean annual flow >100% of baseline flow
No change to mean annual flow slightly higher flow in winter - slightly lower flow in summer
SLR
JSC Nenskra Hydro
NENSKRA HYDROPOWER PROJECT
Supplementary Environmental & Social Studies
Volume 5 - Hydrological & Water Quality Impact Assessment
Map 5.1
Hydrological Impacts
Scale 1:90,000 @ A3
Date February 2017
File n° 901.6.2_ES Project_Location_Main_Compartments_V06Feb2017
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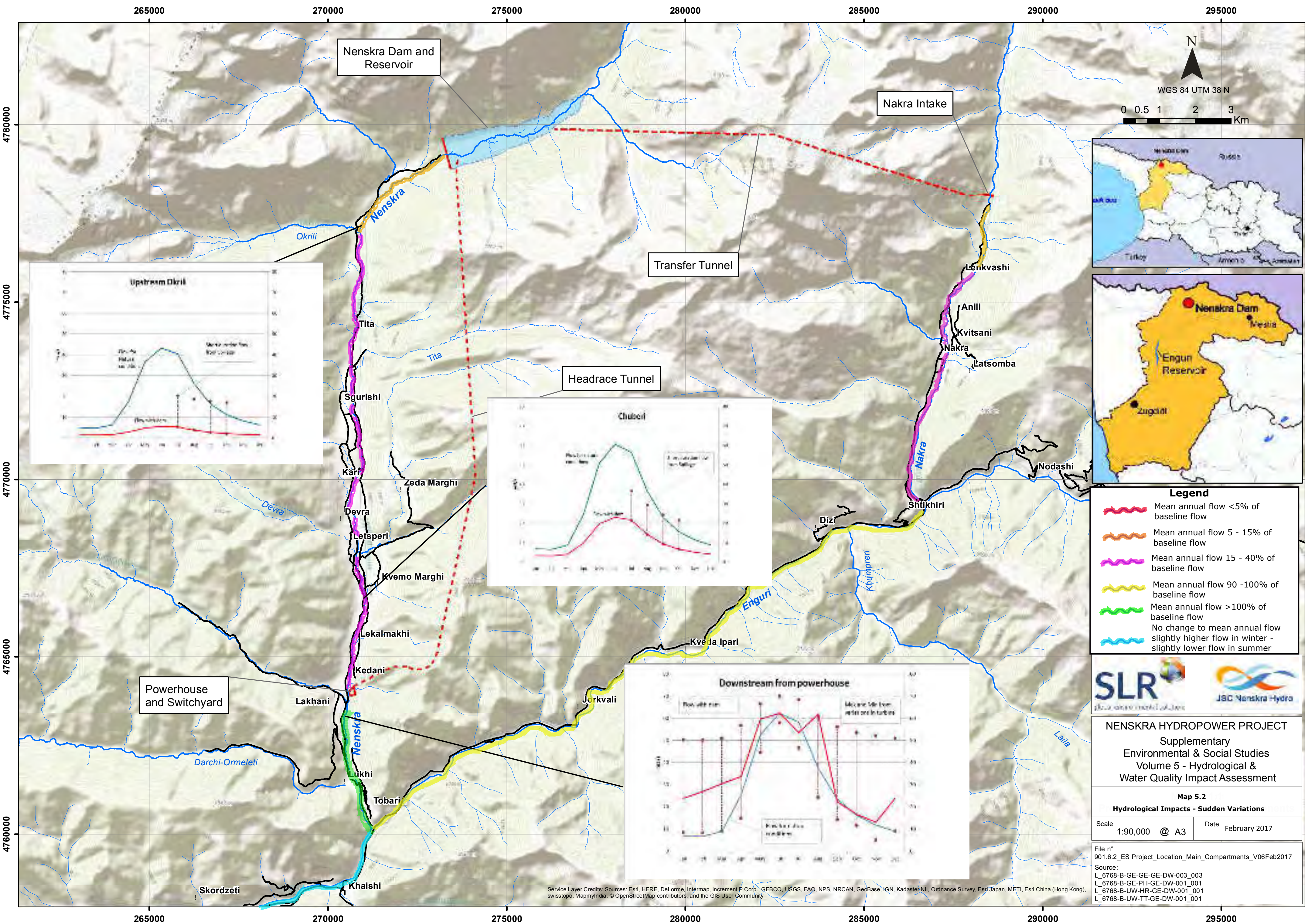

Nenskra Dam and Reservoir
Nakra Intake
Transfer Tunnel
Headrace Tunnel
Powerhouse and Switchyard
Upstream Okrili
Chuberi
Downstream from powerhouse
Nenskra
Okrili
Tita
Devra
Nakra
Enguri
Khumpreri
Darchi-Ormeleti
Laila
Lenkvashi
Anili
Kvitsani
Latsomba
Sgurishi
Kari
Zeda Marghi
Letsperi
Kvemo Marghi
Lekalmakhi
Kedani
Lakhani
Lukhi
Tobari
Khaishi
Skordzeti
Jorkvali
Kveda Ipari
Dizi
Shtikhiri
Nodashi
N
WGS 84 UTM 38 N
0 0.5 1 2 3 Km
Nenskra Dam
Mestia
Enguri Reservoir
Zugdidi
Legend
Mean annual flow <5% of baseline flow
Mean annual flow 5 - 15% of baseline flow
Mean annual flow 15 - 40% of baseline flow
Mean annual flow 90 -100% of baseline flow
Mean annual flow >100% of baseline flow
No change to mean annual flow slightly higher flow in winter - slightly lower flow in summer
SLR
JSC Nenskra Hydro
NENSKRA HYDROPOWER PROJECT
Supplementary Environmental & Social Studies
Volume 5 - Hydrological & Water Quality Impact Assessment
Map 5.2
Hydrological Impacts - Sudden Variations
Scale 1:90,000 @ A3
Date February 2017
File n° 901.6.2_ES Project_Location_Main_Compartments_V06Feb2017
Source:
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5.1.1.2 Downstream of the powerhouse

A. Typical year

Downstream of the powerhouse the Nenskra River flow comprises the combined flow of the upstream flow – which is significantly reduced by the presence of the dam – and the flow from the powerhouse turbines, which comprises the water stored in the Nenskra reservoir and which includes the flow from the Nakra River. The flow of the Nenskra downstream from the powerhouse is very much dependent on the discharge from the powerhouse.

Table 17 and Table 18 on the previous pages present the changes in monthly flow rates and these changes are illustrated on Map 5-1. It can be seen that in general the monthly flow is higher than the natural conditions throughout the year, especially during the winter months though less so during the summer months.

The hourly variations in the flow rate of turbined water are presented in Section 4.5. The hourly variation are expected to cause regular and important variations in the flow rate of the Nenskra River downstream of the powerhouse, as illustrated in the graphs provided in Map 5-2.

For most of the year the maximum hourly flow rates will be slightly less than that of the highest average monthly flow for the natural conditions. However, in May, June and July, the maximum hourly flow occurring 5 hours every day will exceed the highest average monthly flow by about 10 m^3/s. Nevertheless, the natural hourly maximum is probably higher than the average monthly maximum because of hourly variation linked to glacial melt water and the difference between conditions with and without the dam will probably be less than 10 m^3/s.

The hourly variations in river flow with and without the dam for the months of December and June – which represent the months with the highest and lowest flow rates – are illustrated in Figure 9 overleaf. In the figure, the flows for December are compared with the flows in both December and June for the natural conditions (brown and blue lines respectively). This is to illustrate that although the flow rate in December with the dam is increased compared to the natural condition, the flow is less than the natural conditions in June – which is the month with the highest natural flow.

B. Wet year

During a wet year – which occurs 2 years out of every 10 years – for most of the time the flow downstream from the powerhouse will be slightly higher than for a typical year. The increase in the flow will be in the same proportions as for the Nenskra inflow presented in Figure 6 on page 36. The changes in flow rate of the Nenskra for a wet year will therefore be in the same order of magnitude as for a typical year and consequently the computation of the changes in flow rate are not included in this report.

However, during a wet year the Nenskra will be affected by the spillage of reservoir water via the dam spillway during the month of August and this will also affect the flow rate of the Nenskra downstream of the powerhouse. There will be a corresponding increase in flow rate of approximately 10 to 20 m^3/s for a duration of about 2 to 4 hours, and potentially occurring every day when the reservoir is full and most probably in August, but also possibly in September. This would result in a peak flow rate in the order of 90 m^3/s which represents an increase of about 30 m^3/s compared to average flow of 62 m^3/s in June.

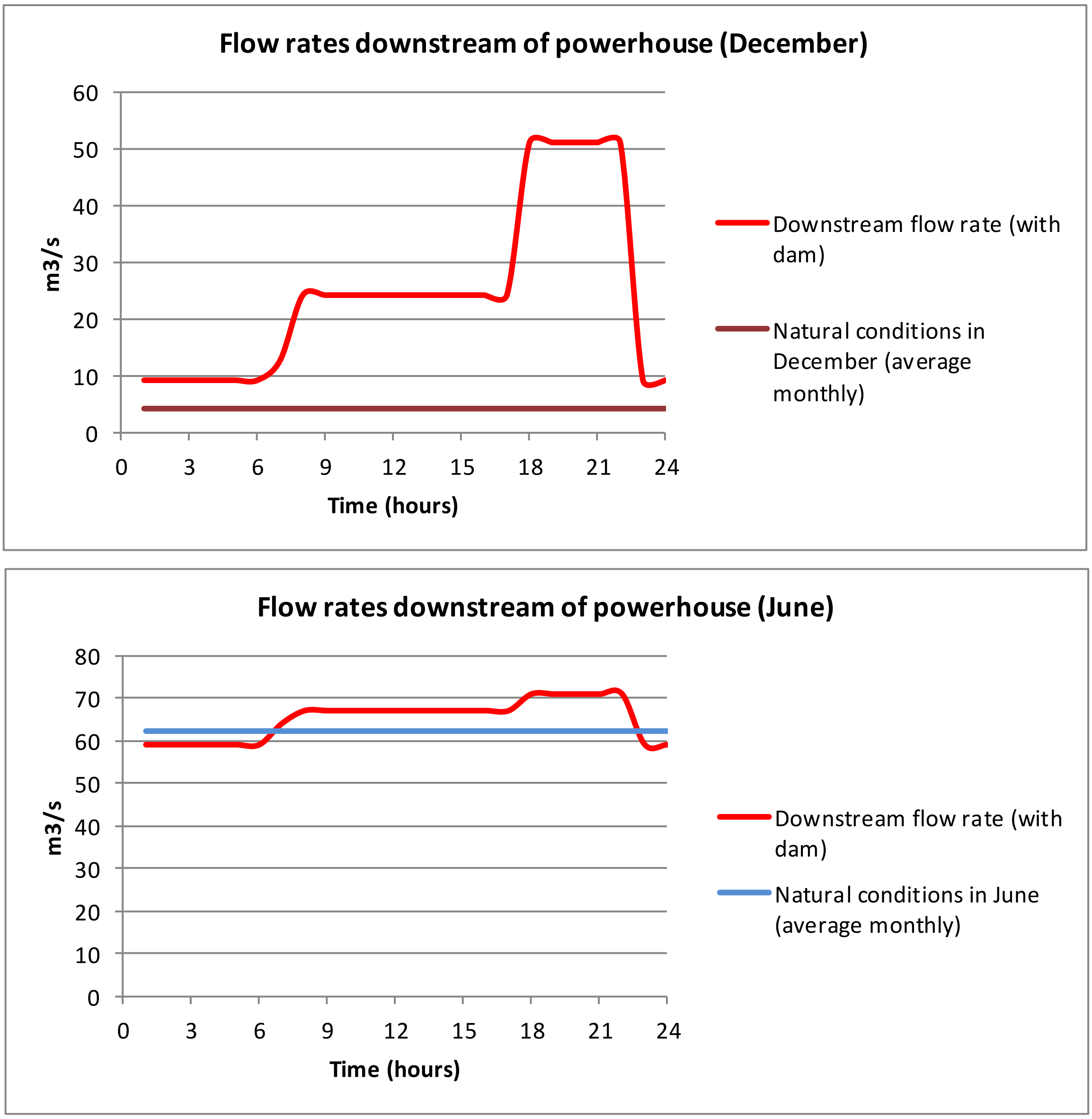


Figure 9 – Nenskra River hourly variations in flow rates downstream of the powerhouse

5.1.1.3 Variations of water level

A. Monthly variations

The variations of water levels corresponding to the variation of the mean monthly flow rates between the situation with the dam (future state) and the baseline conditions (current state) are provided in Table 19.

These impacts have been computed for locations where flow rates have been measured with simultaneous measurements of the water depth, cross-section and water velocity. See Figure 10 for the location of these stations.

The water level in the current and future state is computed according to the Strickler formula. The formula is calibrated (adjustment of the Strickler coefficient) with the measurements carried out in October 2015. The slope of the flow is taken from the longitudinal profile measured with the available DSM (see §2.2).

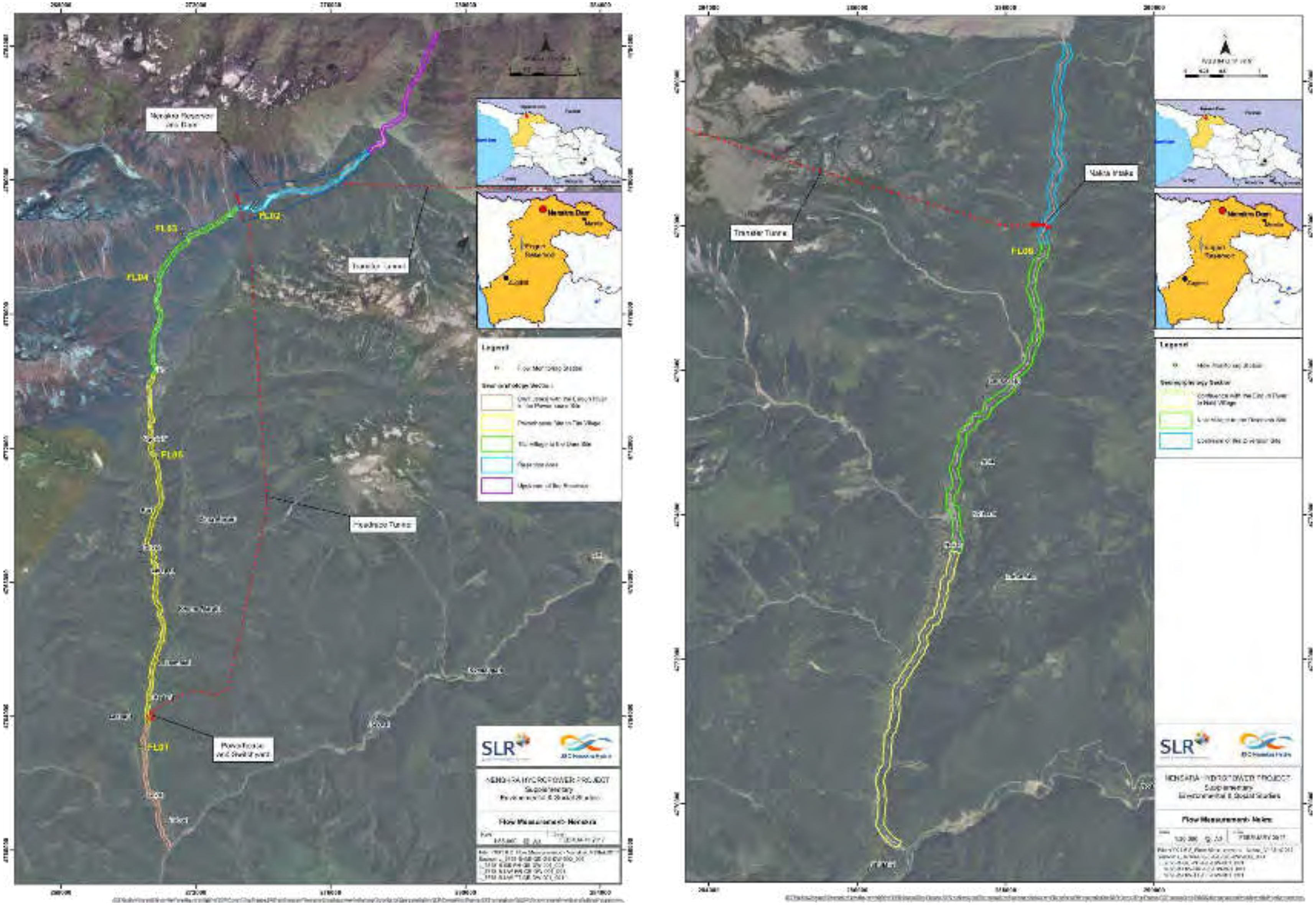


Figure 10 – Location of the flow measurement stations

Table 19 – Changes in average monthly water level for Nenskra River caused by dam

Station / Location	Parameter		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FL01 / Powerhouse	Actual mean discharge	m^3/s	7.0	6.6	8.9	25.3	52.5	62.3	58.1	37.6	23.6	16.1	11.8	8.9
	Actual water depth	m	0.83	0.81	0.90	1.40	2.01	2.21	2.12	1.70	1.36	1.15	1.01	0.90
FL01 / Upstream of powerhouse	Future mean discharge	m^3/s	3.5	3.3	4.2	10.3	20.5	24.1	22.6	14.9	9.7	6.8	5.2	4.2
	Future water depth	m	0.66	0.65	0.70	0.95	1.27	1.37	1.33	1.11	0.93	0.82	0.75	0.70
	Water level variation	m	-0.16	-0.16	-0.20	-0.45	-0.74	-0.84	-0.79	-0.59	-0.42	-0.33	-0.26	-0.20
FL01 / Downstream of powerhouse	Future mean discharge	m^3/s	23.8	26.9	30.5	33.6	59.5	62.3	53.6	61.8	22.2	16.6	13.1	23.9
	Future water depth	m	1.36	1.44	1.53	1.61	2.15	2.21	2.04	2.20	1.32	1.16	1.05	1.37
	Water level variation	m	0.54	0.63	0.63	0.20	0.14	0.00	-0.09	0.50	-0.04	0.02	0.04	0.46

Station	Parameter		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FL02*	Actual mean discharge	m^3/s	4.3	4.1	5.5	15.6	32.5	38.5	36.0	23.3	14.6	9.9	7.3	5.5
	Actual water depth	m	0.72	0.70	0.80	1.36	2.06	2.29	2.20	1.70	1.31	1.07	0.92	0.80
FL02*	Future mean discharge	m^3/s	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
	Future water depth	m	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
	Water level variation	m	-0.32	-0.31	-0.41	-0.96	-1.67	-1.89	-1.80	-1.30	-0.91	-0.67	-0.52	-0.41

Station	Parameter		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FL05	Actual mean discharge	m^3/s	6.0	5.7	7.6	21.6	45.0	53.3	49.7	32.2	20.2	13.7	10.1	7.6
	Actual water depth	m	0.76	0.75	0.81	1.17	1.60	1.73	1.68	1.38	1.14	0.99	0.89	0.81
FL05	Future mean discharge	m^3/s	2.5	2.4	3.0	6.9	13.4	15.8	14.8	9.8	6.5	4.7	3.7	3.0
	Future water depth	m	0.53	0.65	0.58	0.79	0.98	1.04	1.01	0.88	0.78	0.69	0.63	0.58
	Water level variation	m	-0.23	-0.10	-0.23	-0.38	-0.62	-0.70	-0.66	-0.50	-0.36	-0.29	-0.26	-0.23

* Data for FL02 is taken from a location in the future reservoir area immediately upstream form the dam. This was because it was not possible to access the area downstream from the dam because of the steep sides of the banks. It is considered that the flow at FL02 is representative of the flow immediately downstream from the dam because there are no tributaries between these locations.

B. Daily variations

The hourly variations in the flow rate of turbined water (see Section 4.5) will cause regular and important variations in the flow rate of the Nenskra River downstream of the powerhouse. These variations of flow – depicted in Figure 11 below – will result in variations of water level, which will be the most important in February when the Nenskra River flow upstream the powerhouse is the lowest (3.3 m^3/s).

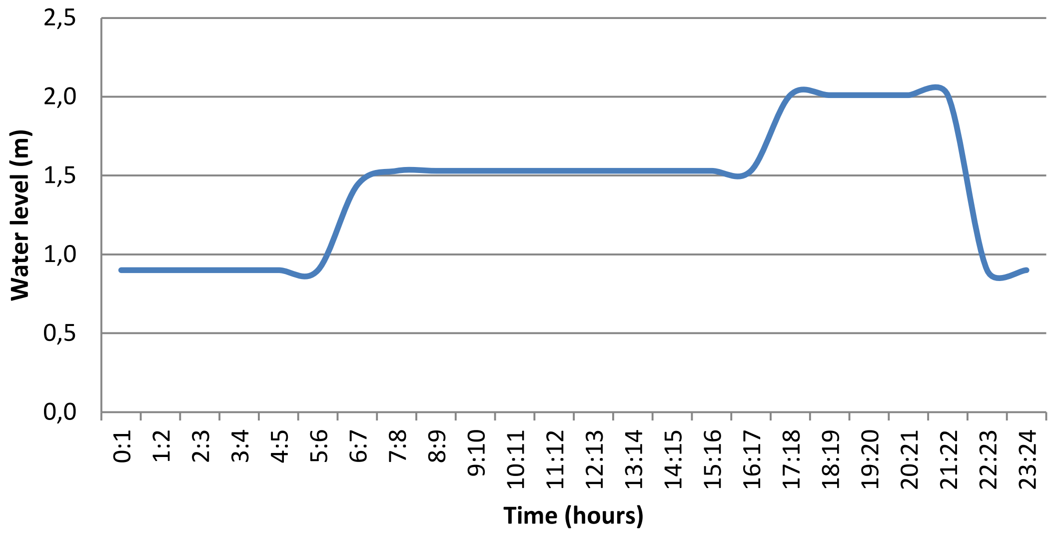


Figure 11 – Predicted daily variations of river water level downstream of powerhouse in February

The greatest variation of river water level downstream of the powerhouse could be observed during the night, when power generation is scaled down. The water level in the river would be lowered by about one meter in less than one hour. In the early morning, the water level could increase by 0.5 meter as power generation is scaled up and at the end of the afternoon, when the maximum power is produced, the water level would be further raised by 0.5 meters in less than one hour.

Downstream from the dam, during a wet year the shutdown of turbines during the night could result in spillage when the reservoir is full most probably in August as described in Section 5.1.1.1. This could potentially occur during the night. In the event of such spillage, there will be an increase in the water level of the Nenskra River downstream from the dam of maximum 1.25 meter for a spillage of 20 m^3/s. The rise of the water level would not be as sudden as it could be downstream of the powerhouse because the Nenskra reservoir will significantly buffer the discharge.

C. Operation of the bottom outlet

The bottom outlet is a safety feature and the gate is normally maintained closed. For safety reasons the gate system comprises two gates in series – these being a service gate and a guard gate. The opening of the gates allows the reservoir water to be released and the reservoir water level to be lowered. The operation of the gates will be subject to strict operating rules and procedures. Situations when the bottom outlet can be expected to opened are follows:

- In the case of suspected degraded dam stability as described (see section 5.1). The reservoir water level is lowered so that the dam can be inspected and reinforced with additional material if necessary;
- When monitoring detects a risk of slope instability or avalanche. The lowering of the reservoir water reduces the likelihood of an impulse wave being generated;

- When a flood event – though not necessarily an extreme flood event – is forecast and the reservoir water level is lowered to best manage the reservoir operation;
- During an extreme flood event and in the case of the blockage or insufficient capacity of the spillway, and
- During the annual testing of the bottom outlet gates.

The gates are equipped with an automated control system and a high integrity safety system to allow the gates to be opened sufficiently to allow a flow rate of 200 m^3/s (equivalent to a 100 year flood event) – which is the flow necessary to comply with ICOLD recommendations for lowering reservoir levels in an emergency situation.

At the time of writing, the operating procedure for the bottom outlet is yet to be defined. However, it can be expected that the venting of sediment or accumulated organic material from the bottom of the reservoir by opening the bottom outlet gates will be required. The sediment venting is described in 6.2.1.1B.

Good industry practice is for the correct functioning of the bottom outlet gates to be verified at least once a year by opening the gates a small amount – generally no more than 10 centimetres. This is performed in accordance with a clear procedure which allows for opening of the gates in stages. The risks associated with the rapid increase of the flow – and potentially of the water level – can be anticipated and managed (including the case of gate blockage) since the gate test is an action that is planned and organised in advance. It should also be noted that for safety reasons the service gate is tested behind the guard gate without releasing any water.

D. Mitigation measures

The rapid increase of water level downstream of the powerhouse and downstream of the dam could represent a danger for persons, wild animals or livestock present in the riverbed (e.g. on small islands) or along the banks when the event occurs. Aquatic biodiversity – such as fish sheltering in 2 kilometre reach immediately downstream from the dam could also be impacted. The public safety issues are addressed in Vol. 3 Social Impact Assessment and in Vol. 6 Natural Hazard and Dam Safety. Potential impacts on biodiversity are evaluated in Vol. 4 Biodiversity Impact Assessment.

It is normal industry practices to shut down/start-up turbines and to open bottom outlets in stages to avoid the creation of hazards downstream of the facility. However, in the case of a sudden breakdown there may be a sudden stopping of turbines. Nevertheless, this type of event is very infrequent because of the inspection and maintenance programmes aimed at avoiding unplanned unavailability. Rules regarding shutdowns will be specified in the operating procedure of both the reservoir and the powerhouse. The operator will further communicate on these operating procedures with the local community as part of the regular meetings to be held with the villagers during the project construction and operation phases. These measures are referred later in this report as:

- [WAT 12] Powerhouse and reservoir operating procedures established to avoid creation of hazards for downstream users.
- [WAT 13] Communication with downstream users on operating procedures.

Within the immediate vicinity of the powerhouse and dam site, it is also normal industry practice to create exclusion zones (e.g. fencing) to prevent the general public entering these areas. It is also normal practice to install sirens, warning systems and information panels to alert any persons located close to the bottom outlet, the spillway plunge pool or the tailrace of the immediate activation of the facility. These measures commitments are referred later in this report as:

- Exclusions zones and access restrictions are created in operating areas and immediately downstream of dam site and powerhouse.
- Install warning signs, siren systems and conduct appropriate drills to test effectiveness at various distances from the dam and powerhouse.
- Conduct regular public information campaign to raise awareness about timing and magnitude of normal operation downstream releases.

These measures are referred to later in this report as:

- [WAT 14] Access restrictions and warning systems downstream of dam site
- [WAT 15] Access restrictions and warning systems downstream of powerhouse
- [WAT 16] Public awareness campaigns

All the above measures are captured in vol. 8 ESMP and the measures specific to community safety are integrated into the Emergency Preparedness Plan.

With regard to the mitigation of potential impacts to aquatic biodiversity, a specific ESIA for venting the sediment by opening the bottom outlet will be prepared and which will evaluate the risks to biodiversity and identify mitigation measures. It is considered that an ESIA is considered because in 15 or 20 years' time, when the first sediment venting is expected to be required, the land use along the river will have changed and communities could have a different usage of the Nenskra River water than the current situation. Consequently, it will be necessary to perform a new baseline of the rivers water use - both by communities and for fish - and adapt the sediment venting procedure accordingly.

This measure is referred to later in this report as:

- [WAT 17] Preparation of a sediment venting ESIA and implementation of recommended mitigation measures prior to the first opening of the bottom outlet for sediment venting purposes.

5.1.2 Floods events when Nenskra reservoir at full supply level

In the case of a flood event occurring when the Nenskra reservoir is at maximum operating level, the flood water will overflow via the fixed weir spillway, pass through the spillway and be discharged into the Nenskra downstream from the dam. In this case, the flow in the Nenskra between the dam and the powerhouse will be much the same – though slightly lower[3] as the situation for natural conditions (without the dam). This is assuming that: (i) there is no additional discharge – such as by lowering the water level of the reservoir by opening the bottom outlet gate; and (ii) the additional inflow from the Nakra via the transfer tunnel is stopped by closing the Nakra transfer tunnel inlet gate, and (iii) that during a flood event the turbining is stopped. Therefore, during a flood event, the hydropower scheme will not increase flood flow rates of the Nenskra River between the dam and the powerhouse - in fact flow rates will be slightly lower.

For smaller more frequent flood events it is probable that turbining will continue, in which case flood flows between the dam and powerhouse will be those of natural conditions less the 46.9 m^3/s which is the turbining rate. If the Nakra transfer tunnel malfunctions and cannot be closed the flood flows could be increased by 45.5 m^3/s compared to the natural situation.

The Project Company will check if there is an increase in the risk of flooding properties or the road situated along the reach extending 1 kilometre downstream from the powerhouse – and

[3] The reservoir will naturally attenuate flood peaks and so the flood peak with the reservoir will always be slightly lower than under natural conditions.

taking into account all foreseeable operational events. If flooding is probable in the lifetime of the Project, the Project Company will mitigate potential flooding my adopting operating rules to prevent flooding and where this is not possible land exposed to flooding risk will be subject to land acquisition. However, the Project will not have an obligation to acquire land that would be flooded by natural flood event without the dam.

During normal operation the Nenskra Project should not result in increased flood flow rates and the presence of the dam should reduce the peak flow and duration of flood events – as flood waters will be retained partially by the reservoir until reservoir water reach the full supply level and overflow via the spillway.

The flood study is linked to flood studies related to the Emergency Preparedness Plan addressing abnormal and accidental events discussed in Vol. 6 Natural Hazards and Dam Safety. The flood studies will be completed in 2019 as part of the Emergency Preparedness Plan and before reservoir filling starts. This measure is referred later in this report as:

- [WAT 18] Flood studies include the reach downstream from the powerhouse to the confluence with the Enguri River and establish if flood protection structures are required for normal operations.
- [WAT 19] Flood protection and mitigation measures (if any) identified in the flood studies for downstream from the powerhouse, included in the Project design.

Further downstream, the valley is very deep and no significant impacts are expected.

5.2 Predicted hydrology changes downstream of the Nakra diversion

5.2.1 River flow

The monthly flow rates predicted at strategic points along the river for a mean year have been computed with and without the diversion and are presented in Table 20 and Table 21 and illustrated in Map 5-1 – Hydrological impacts.

5.2.2 Variations of water level

The variations of water levels corresponding to the variation of the mean monthly discharges between the future state and the current sate are given Table 22. These impacts have been computed where river flow measurement has been carried out with simultaneous measurements of the water depth, cross-section and velocity. The water level in the current and future state is computed according to the Manning-Strickler formula. The formula is calibrated (adjustment of the Strickler coefficient) with the measurement carried out in October 2015. The slope of the flow is taken from the longitudinal profile measured with the available DSM (c.f. §2.2).

Table 20 – Average monthly flow rates of Nakra River with Project

Location on Map 2.1	Future Catchment area parameters				Future Mean monthly discharge (m^3/s)											
	Location	Approx. Distance from Enguri confluence (km)	Catchment Area without upstream intake area (km²)	Catchment Mean Elevation (m asl)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Sanitary flow (m^3/s)				1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
NA0	Enguri Confluence	0	65	2,186	2.3	2.2	2.4	4.5	7.8	9.8	10.1	7.5	4.8	3.6	2.9	2.5
NA1	Nakra Bridge	4.4	40	2,267	1.9	1.9	2.0	3.4	5.6	7.0	7.2	5.4	3.6	2.8	2.4	2.1
NA2a	Downstream Lekverari Confluence	5	36	2,334	1.9	1.8	1.9	3.2	5.4	6.6	6.8	5.1	3.5	2.7	2.3	2.0
NA2b	Upstream Lekverari Confluence	5.3	17	2,120	1.5	1.5	1.5	2.1	2.9	3.4	3.5	2.8	2.1	1.8	1.7	1.5
NA3a	Downstream Laknashura Confluence	7.9	12	2,308	1.4	1.4	1.4	1.9	2.6	3.0	3.0	2.5	1.9	1.7	1.6	1.5
NA3b	Upstream Laknashura Confluence	8	6	2,308	1.3	1.3	1.3	1.5	1.9	2.1	2.2	1.9	1.6	1.5	1.4	1.3
	Downstream Water Intake	10.0	0	2,190	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2

Table 21 – Changes in average monthly flow of Nakra River caused by Project

Location on Map 2.1	Future Catchment area parameters				Future variation of the mean monthly discharge (m^3/s)											
	Location	Approx. Distance from Enguri confluence	Catchment Area without upstream intake area	Catchment Mean Elevation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Sanitary flow (m^3/s)				1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
NA0	Enguri Confluence	0	62	2,186	-1.0	-0.9	-1.2	-5.6	-12.6	-16.7	-17.4	-11.8	-6.3	-3.8	-2.4	-1.5
NA1	Nakra Bridge	4.4	40	2,267	-1.2	-1.0	-1.4	-6.1	-13.6	-18.0	-18.7	-12.7	-6.8	-4.1	-2.7	-1.7
NA2a	Downstream Lekverari Confluence	5	34	2,334	-1.2	-1.1	-1.4	-6.2	-13.9	-18.3	-19.1	-13.0	-7.0	-4.3	-2.8	-1.7
NA2b	Upstream Lekverari Confluence	5.3	15	2,120	-1.3	-1.1	-1.5	-6.4	-14.3	-18.9	-19.7	-13.4	-7.2	-4.4	-2.9	-1.8
NA3a	Downstream Laknashura Confluence	7.9	9	2,308	-1.2	-1.1	-1.5	-6.3	-14.1	-18.6	-19.4	-13.2	-7.1	-4.3	-2.8	-1.8
NA3b	Upstream Laknashura Confluence	8	3	2,308	-1.2	-1.0	-1.4	-6.2	-13.8	-18.2	-19.0	-12.9	-6.9	-4.2	-2.7	-1.7
	Downstream Water intake	9.97	0	2,190	-1.2	-1.0	-1.4	-6.2	-13.8	-18.3	-19.1	-13.0	-7.0	-4.2	-2.8	-1.7

Table 22 – Changes in average monthly water levels of the Nakra River caused by Project

Location	**FL06 Downstream Water Intake**		Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
FL06	Actual mean discharge	m^3/s	2.4	2.2	2.6	7.4	15.0	19.5	20.3	14.2	8.2	5.4	4.0	2.9
	Actual water depth	m	0.59	0.57	0.60	0.84	1.11	1.25	1.27	1.09	0.87	0.75	0.68	0.62
FL06	Future mean discharge	m^3/s	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
	Future water depth	m	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	Water level variation	m	-0.14	-0.38	-0.41	-0.65	-0.93	-1.07	-1.09	-0.90	-0.68	-0.56	-0.49	-0.43

5.3 Impact on the Enguri River and on the Enguri HPP

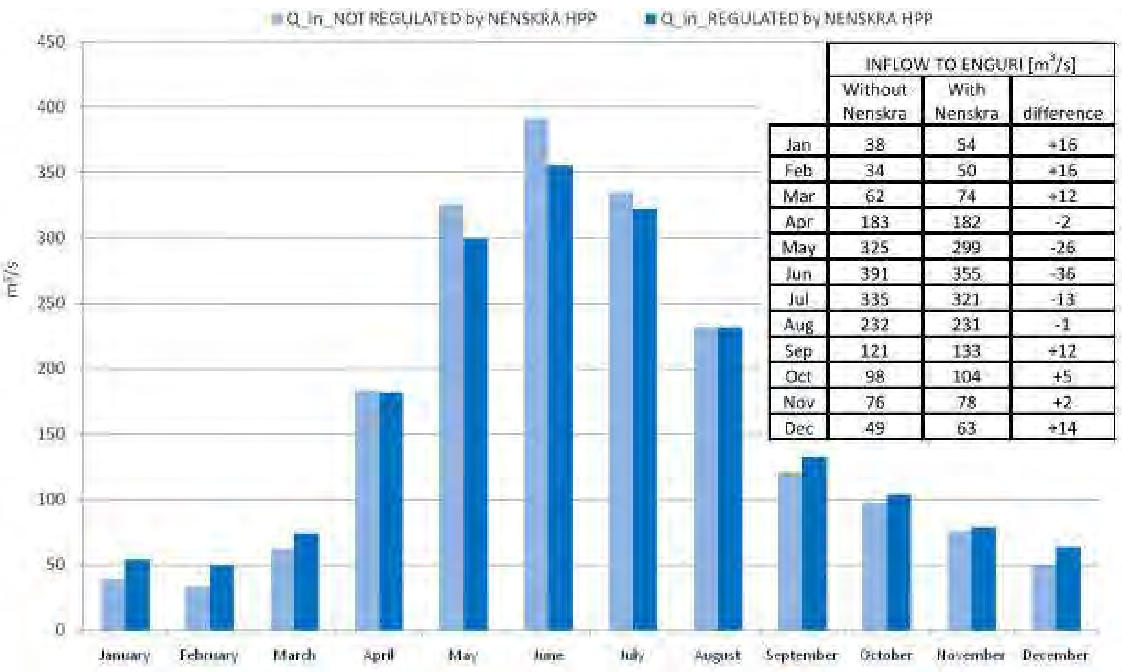
5.3.1 Impact on the Enguri flow upstream of the Enguri reservoir

The Project will result in a lowering of the annual mean flow of the Enguri River between the Nakra River and the Nenskra River confluence. The decrease is a result of the water transfer from the Nakra diversion weir to the Nenskra reservoir.

The reduced inflow from the Nakra represents an average between 7.5 and 8 m^3/s. At the Dizi gauging station on the Enguri River, downstream of the Nakra confluence, the mean annual flow is 74.4 m^3/s. Consequently the impact is a decrease of about 10 percent of this mean annual flow.

Once the Nenskra reservoir has been filled, the annual mean flow of the Enguri River flow downstream of the confluence with the Nenskra confluence is not modified as, over a full year, the discharge diverted towards the Nenskra reservoir is returned to the Enguri River at the Nenskra confluence. The losses from evaporation have been calculated to represent on average 0.04 m^3/s – which is negligible (0.05 percent) compared to the mean annual inflow. However, the monthly inflow of the Nenskra into the Enguri will be modified. Table 23 presents the mean monthly variation of the flow caused by the Project.

The monthly inflow into the Enguri reservoir with and without the Nenskra hydropower scheme is presented in Figure 12 below.



	Without Nenskra	With Nenskra	difference
Jan	38	54	+16
Feb	34	50	+16
Mar	62	74	+12
Apr	183	182	-2
May	325	299	-26
Jun	391	355	-36
Jul	335	321	-13
Aug	232	231	-1
Sep	121	133	+12
Oct	98	104	+5
Nov	76	78	+2
Dec	49	63	+14

Figure 12 – Monthly inflow into the Enguri reservoir – with and without Nenskra HPP

Source: Stucky, 2015

The inflows to the Enguri reservoir have been used to estimate flows at the Dizi location (downstream Nakra confluence) and for the Khaishi location (downstream Nenskra confluence). The estimate has been made using the ratio of the mean annual flows at these gauging stations and the mean annual flow at the Jvari gauging station located near or at the Enguri dam.

Flows will vary with the inter-annual variations in hydrology and turbine discharge. However, the trend will be that (i) Enguri River flow is systematically decreased downstream of the

Nakra confluence (about 6 percent in winter, 8 percent in spring, 11 percent in summer and 7 percent in autumn), and (ii) downstream of the Nenskra confluence, the Enguri River flow is increased in winter (between 30-55 percent), not significantly modified in spring and decreased in summer and autumn (4 to 7 percent) with an exception in August when a slight increase is predicted. Nevertheless, it should be noted that although there will be a slight loss of Enguri electricity production during the Nenskra reservoir filling; this is balanced by the subsequent increased electricity production caused by the increased regulation capacity of the Enguri inflow.

5.3.2 Effect of the Nenskra reservoir impoundment period on the Enguri HPP inflow and operation

The Nenskra reservoir volume is 176 million cubic metres at the maximum operating level (1,430 metres). The planned time to fill the reservoir is 10 to 12 months in two phases (start in Q3 2018) depending on the month of the start of filling, and considering the mean monthly hydrology. The time could be longer in the case of a dry year. It should be noted that the reservoir filling is performed in 2 phases in order to allow power generation to start before the dam structure construction is completed and which is planned for Q4 2020.

During this filling, a loss of inflow to the Enguri reservoir will be observed, representing a loss of hydropower production by the Enguri power plant. The mean Enguri reservoir inflow is 5,106 million cubic metres per year (Stucky, 2015). The loss of inflow caused by the impoundment of the Nenskra reservoir represents 3.6 percent of the Enguri annual inflow for the year of the Nenskra filling. There will be no loss for subsequent years, and there will be increased power production because of the increased storage capacity

GSE as the National Dispatching Centre in Georgia was met by the Environmental & Social Team in April 2016 during the preparation of the present document. The loss of inflow during the first impoundment was qualified as unavoidable but minor compared to the long-term benefit of the Nenskra HPP for the Enguri during the winter period. This first engagement step with GSE will continue during the next stages of the Project implementation. This measure is referred later in this report as:

[WAT 20] Coordination with GSE and Enguri HPP.

Table 23 – Changes to average monthly flow rates of Enguri River caused by dam

Enguri River	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Downstream Nakra Confluence												
Additional discharge (m^3/s)	-1.2	-1.0	-1.4	-6.2	-13.8	-18.3	-19.1	-13.0	-7.0	-4.2	-2.8	-1.7
Percentage of Enguri discharge	-6%	-6%	-4%	-7%	-8%	-9%	-11%	-11%	-11%	-8%	-7%	-7%
Downstream Nenskra Confluence												
Additional discharge (m^3/s)	15.7	19.2	20.3	2.4	-6.5	-17.8	-23.1	11.5	-8.1	-3.6	-1.4	13.4
Percentage of Enguri discharge	54%	73%	42%	2%	-3%	-6%	-9%	6%	-9%	-5%	-2%	35%
Enguri Reservoir												
Natural inflow to reservoir (m^3/s)	38	34	62	183	325	391	335	232	121	98	75	49
Additional discharge (m^3/s)	15.7	19.2	20.3	2.4	-6.5	-17.8	-23.1	11.5	-8.1	-3.6	-1.4	13.4
Percentage of Enguri discharge	41%	56%	33%	1%	-2%	-5%	-7%	5%	-7%	-4%	-2%	27%

5.4 Impact on groundwater

Natural springs are situated in the Nakra and Nenskra valleys, and these are used on a daily basis by the local communities for the supply of potable water. The springs are located above the highest water levels of the rivers.

The water quality survey identified that the electrical conductivity of the spring water was in all cases higher than that of the river water, and that local communities reported that the spring water was available during the winter months when river water was at its lowest. This suggests that the spring water is fed primarily from aquifers and probably only marginally affected by river water levels.

The Nakra transfer tunnel construction works are not expected to have a discernible effect on the availability or quality of spring water used by local communities in the Nenskra and Nakra valleys because the tunnel will be located over 10 kilometres from the nearest springs used by local communities.

The headrace tunnel which conveys water from the reservoir to the powerhouse is situated deep within the mountain to the east of the Nenskra valley some 4 kilometres from the Nenskra River. Consequently, it is unlikely that the tunnel boring work or the physical presence of the tunnel will have any discernible effect on springs and groundwater resources in the Nenskra valley.

The underground works that are situated closest to communities are the Tunnel Boring Machine launching tunnel near the powerhouse and the penstock. Any springs located near the entrance to these tunnels may be affected by either modified quality or reduced quantities.

As local people report that in the past other hydropower projects have resulted in reduced water from springs near rivers reduced in flow by hydropower projects, it cannot be excluded that similar impacts may be observed in the case of the Nenskra Project. Consequently, spring water quality and availability will be monitored as described in Vol. 3 – Social Impact Assessment. Monitoring will start before the start of tunnelling works and reservoir filling so that project induced impacts can be differentiated from seasonal and inter-annual variations. When necessary any issues related to spring water will be managed by the grievance mechanism described in Volume 7 – Stakeholder Engagement Plan. The Project has made a commitment to provide an alternative supply of water to affected communities to replace existing water supplies that are affected by the Project.

5.5 Monitoring programme

5.5.1 Objective

The hydrological monitoring programme described in this section is for environmental purposes. The objectives are to: (i) demonstrate that the mandatory ecological flows downstream of the Nenskra dam and Nakra diversion weir are indeed operational, and (ii) establish the actual flow rates of the Nenskra and Nakra rivers once the scheme is in operation. This second objective is so that impacts on hydrology can be measured and so that medium and long term hydrology change trends can be recorded, which is of use for designing other hydropower schemes in the watershed or for making future operational modifications to the Nenskra scheme.

The water level monitoring in the Nenskra reservoir, the Nenskra river flow upstream of the reservoir, the discharge of turbined waters and the quantities of reservoir water spilled via the spillway will be monitored for operational and safety purposes and are not discussed in this section.

5.5.2 Type of monitoring and frequency

The hydrological monitoring will require two types of monitoring stations to be established: (i) simple structures that will allow a visual check (as part of community participatory monitoring) that the river flow is equal or greater than the mandatory ecological flow, and (ii) permanent gauging stations with recording of river flow. The design of the simple structures and gauging stations will be made at a later stage in the Project.

From a functional perspective, the simple structure shall be designed so that there is an open channel where a visible flow of water can be observed when the river flow is equal or higher than the mandatory ecological flow rate. As an example, the structure could consist of a concrete slab with a central open channel. The dimension of the structure will be defined so that when the river flow is greater than the mandatory ecological flow rate, the central channel overflows and water flow can be visually observed on the surface of the concrete slab. As indicated in [WAT 6] in section 4.7, there will be a system for real-time monitoring of the ecological flow and disclosure on a website, and to this end a webcam could be used.

This measure is referred to later in the report as:

[WAT 21] Hydrological monitoring and real-time monitoring and disclosure on a website of the ecological flow.

Monitoring for geomorphological impacts are described in section 6.3.2 and monitoring of water quality impacts is described in section 7.7.2.

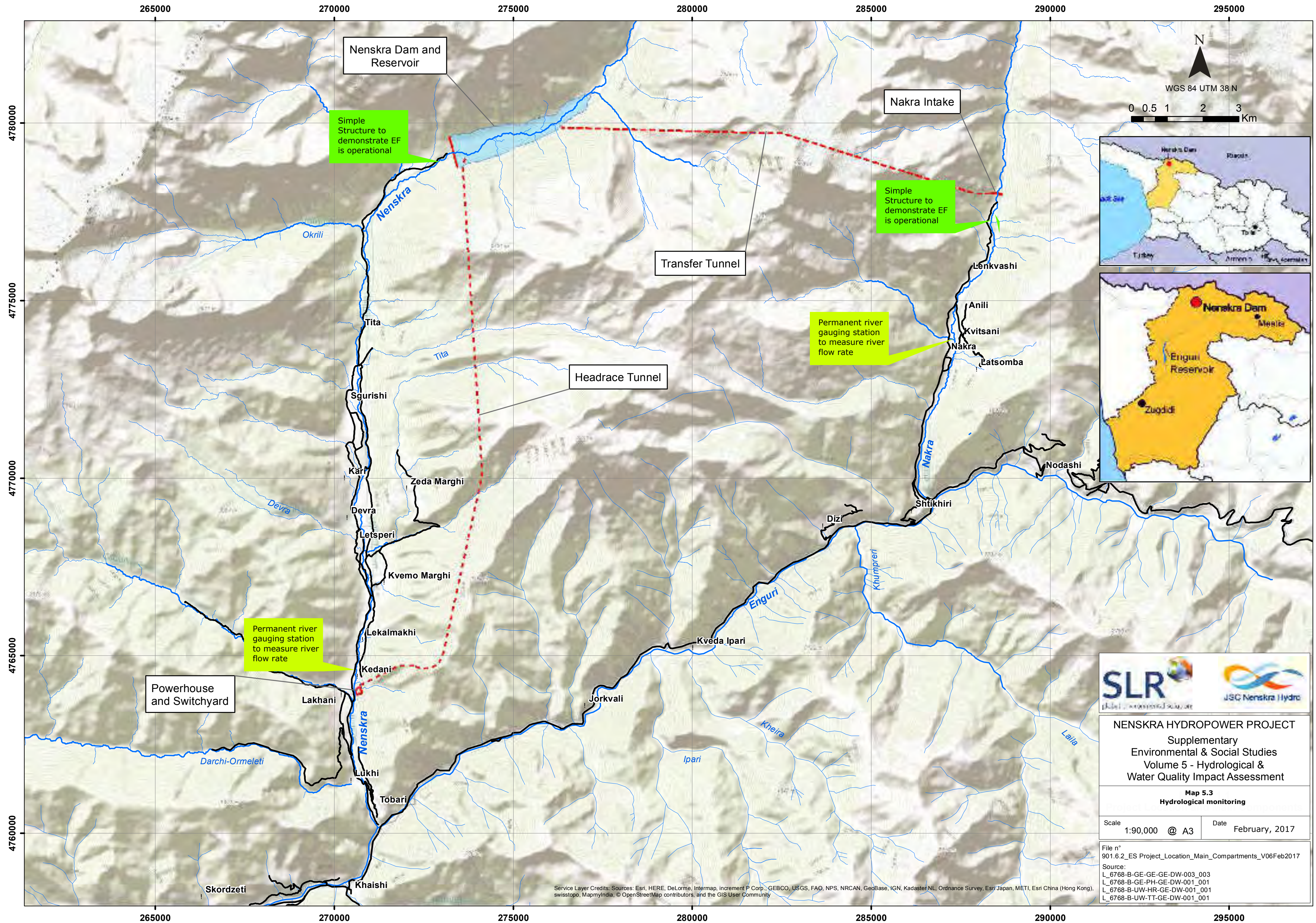
5.5.3 Parameters

Parameters to be monitored are as follows:

- Simple structures immediately downstream of the Nenskra dam and Nakra diversion weir will allow a visual check to be made that the ecological flow is maintained or not, and
- River gauging stations which are (i) on the Nenskra River immediately upstream of the power house, and (ii) on the Nakra River immediately upstream of the Nakra village. If the stations are automated, they will measure on a continuous basis the river flow rate. If the stations are of water level gauge type, the measurement will be made twice per day in the Nenskra valley and once per day in the Nakra valley.

5.5.4 Stations

Map 5-3 overleaf below illustrates the location of the proposed hydrological monitoring stations.



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Map 5.3
Hydrological monitoring

Scale 1:90,000 @ A3
Date February, 2017

File n°
901.6.2_ES Project_Location_Main_Compartments_V06Feb2017
Source:
L_6768-B-GE-GE-GE-DW-003_003
L_6768-B-GE-PH-GE-DW-001_001
L_6768-B-UW-HR-GE-DW-001_001
L_6768-B-UW-TT-GE-DW-001_001

6 Geomorphological impact assessment

6.1 Description of the baseline geomorphology

6.1.1 General description

A general description of the baseline situation from a hydrological perspective is provided in §2.1 and §3.1.3.

Low river flow is observed in winter from December to March and high flows in spring and summer from May to August. The transport of sediment is consequently observed mainly from May to September.

A field survey of the Nakra River and of the Nenskra River geomorphology has been carried out covering the reaches downstream from the Nakra diversion weir and the Nenskra dam. The purpose of the survey was to observe:

- The river's bedload;
- The tributaries' bedload at the confluences, and
- The possible landslides along the river banks.

A. Nakra River

The Nakra riverbed typically includes a layer of large boulders, which acts as a protection against erosion and referred to as being "armoured". The sediment in the Nakra River originates mainly from its two main tributaries – the Lekverari and the Laknashura – both of which have torrential flow and transport sediment. There are also large screes and steep tributaries in the upper catchment. Also, there are landslides directly into the Nakra River and erosion of the river banks.

The Lekverari torrent discharges into the Nakra River at the Nakra village and transports important quantities of sediment. A large alluvial fan has been created at the confluence with the Nakra. See §3.1.3 for more details.

The Laknashura torrent, further upstream from the Nakra village, also has a wide alluvial fan with many branches and which transports significant amounts of solid material into the Nakra. See §3.1.3 for more details.

There is some localised and infrequent erosion of the river banks. Boulders – originating from the material constituting the banks and landslides – protect the lateral banks from erosion, and it is only very rare strong currents that can move the boulders and erode the banks.

B. Nenskra

No significant sediment transport was observed in the Nenskra River's tributaries. Though, an exception is the torrent located just downstream from the dam, but whose discharge will be diverted into the reservoir as part of the Project. The key points regarding transport of solid material in the Nenskra is as follows:

- The riverbed is armoured by boulders;

- The sediment originated mainly from lateral local landslide of steep and high banks, and
- Contrary to the Nakra village, the Nenskra riverside residents do not mention the sediment transport as an issue.

The main sediment issues related to the Nenskra River are:

- Lateral bank erosion where the road or houses are near the river. In Chuberi, some bank protections are made of gabions, and
- The dumping of sawdust or pieces of boards on the river banks or on the tributaries banks which are conveyed by the floods up to the downstream reservoir of the Enguri dam.

C. Enguri

The Enguri River between the Nakra River and the Nenskra River flows in a narrow valley. The projected Khudoni Hydropower Project reservoir is planned to occupy the narrowest section of the Enguri River gorge which is upstream from the Enguri reservoir.

The Enguri River is much wider (about 40 metre wide) than the Nenskra River (about 20 metres) and is armoured by large boulders. Two large tributaries of the left bank of the Enguri are supplying a lot of sediment in large delta into the Enguri River, downstream of the Nakra confluence (near Dizi) and downstream of the Nenskra confluence (near Khaishi).

6.1.2 Input data and field survey

The hydrological data and the topographical data collected are used for the computation of the bedload sediment transport impact.

Solid material observed in the rivers is of various diameters: boulders (10 cm to 30 cm), gravels and sand (0.2 – 1 mm diameter). The boulders represent a protective layer at the bottom of the riverbed. The fine sediment comes from the lateral bank landslides.

Very fine sand is observed in large quantities in the inundated area of the future reservoir. This sediment is expected to remain in place once the area has been flooded and the reservoir created.

6.1.3 Assessment methodology

The study has been carried out considering the locations where discharges and cross section have been measured and where hydraulic characteristics have been computed.

The methodology of the study is as follows:

- As various sizes of sediment are found in the rivers, computations are made with the following grain size diameters : 20 cm, 10 cm, 5 cm, 1 cm, 2 mm;
- The bedload transport capacity is computed according to the Meyer-Peter formula which is appropriate for this kind of river;
- The initial movement of the sediment transport is computed according to the Shields Theory;
- The considered hydrological conditions are : mean monthly discharge (period 1956-1986), and flood discharge (observed during the months of June, July or August);
- The present state capacity of sediment transport and the future state capacity of sediment transport (bedload) are computed and compared at the same locations, taking into account the variation of the hydrological conditions caused by the hydropower scheme;

- The computation concerns the deepest part of the cross-section where the main sediment transport is observed and where the maximal grain size diameter may be moved.

It has been found that the rivers' sediment transport capacity is higher than the available sediment. The large boulders armouring the rivers move rarely and the fine sediment that can be transported is made available mainly after landslide events and when melting snow runoff erodes soil.

The sediment transport capacity is a good indicator of the impact of increased sediment in the river during construction, as river sediment transport capacity is important and increased sediment in the river resulting from construction activities will probably be comparable to sediment loading from landslide events.

The impact of the Project is computed taking into account, for the mean monthly discharge as well as for the flood discharges:

- The variation of the natural runoff caused by the modifications of the catchment areas boundaries, including:
  - Reduction of catchment area upstream of the Nakra water intake and upstream of the Nenskra dam, and
  - Variation (lowering) of the mean elevation of the reduced catchment areas which impacts the runoff calculated using the regional study chart.
- The Project's operation which includes:
  - Ecological flows maintained in the rivers downstream of the Nakra diversion weir: 1.2 m^3/s; and Nenskra dam: 0.85 m^3/s), and
  - Energy production: turbined water discharges from the powerhouse to the Nenskra River.
- Monthly flows at the strategic locations are calculated using the ratios of annual: monthly flow established for the gauging stations.

6.1.4 Description of past landslide events and consequences

Large landslides are known to have occurred on the Nakra River's tributaries – Lekverari and Laknashura. The events resulted in very high sediment transport and mudflow. The frequency of such events is estimated to be about once in every 10 years. Within the scope of this study it has not been possible to make further investigations regarding possible other large landslides in the high upper reaches of the Nakra and Nenskra tributaries.

Frequent landslides events probably occur where steep banks are observed along the rivers. Such events are expected to occur in periods of heavy rains and/or by erosion of the foot of the banks by the river. These localised landslides affect lateral slopes with height of between 10 to 30 metres and cause fine sediment and some boulders to enter the river.

The sediment material introduced by these landslides into the rivers is washed away by the floods. The large boulders stay near the foot of the landslide and are moved only by the largest floods over short distances. All the fine sediment is transported into the Enguri reservoir. If the Khudoni scheme is built, it will be trapped in this new reservoir (unless bypass or frequent venting is planned in the design).

6.2 Assessment of geomorphological changes

6.2.1 Predicted changes in sediment transport

6.2.1.1 Long-term modification to riverbed downstream of Nenskra reservoir

A. Normal operation – Chuberi area, upstream and downstream of powerhouse

Table 25 presents the average monthly modifications to the bedload sediment transport upstream and downstream of the powerhouse in terms of:

- Maximal sediment grain size that can be moved;
- Possible period of bedload sediment transport, and
- Sediment bedload transport capacity for 5 mean grain size diameters (d=20 cm, 10 cm, 5 cm, 1 cm, 0.2 cm).

Table 24 presents the conclusions in terms of trend and orders of magnitude.

Table 24 – Summary of conclusions – Predicted trends of geomorphological changes

Characteristic	Upstream of powerhouse		Downstream of powerhouse	
	Baseline situation	Situation with dam	Baseline situation	Situation with dam
Transport of gravel of 0.2 – 1 cm diameter	Transported all year	Transported all year Decrease in transport capacity of 50-55% compared to baseline	Transported all year	Increased capacity Dec., Jan, Feb, March, April, May, August No Change June, July, Sept., Nov
Transport of gravel of 5 cm diameter	Transported April – August	Transported May – August Decrease in transport capacity of 85-90% compared to baseline	Transported all year	Increased capacity Dec., Jan, Feb, March, April, May, August No Change June, July, Sept., Nov
Transport of boulders of 10 cm in diameter	Can be transported in the period May – August	Cannot be transported	Can be transported in the period May – August	Can be transported in the period May – August, with 60% increase in capacity in May and 100% in June and August, and decreases 25% in July.
Largest solid material that can be moved in May, June and July	Material 15-16 cm in diameter	Material 9-10 cm in diameter	Material 15-16 cm in diameter	Material 15-16 cm in diameter
Transport of boulders of >20 cm in diameter	Flood event required	Flood event required	Flood event required	Flood event required

The overall conclusions can be summarised as follows:

- No significant changes downstream of the powerhouse are expected in terms of sediment transport. It is considered unlikely that the riverbed armouring could be eroded by the increased flow rate of the river because the maximum flow rate is not significantly different from the natural maximum flow rate observed in June and July. Similarly, the hourly variations in turbined flow and the consequent important changes in Nenskra river flow are also not expected to cause erosion of the riverbed.

- It is possible that the slightly higher flow rates of the Nenskra downstream from the powerhouse – compared to those of natural conditions (excluding flood events) – and which occur more frequently and for longer duration that natural conditions – could cause localised erosion of riverbanks. The area at risk comprises the 2 kilometres immediately downstream of the powerhouse which is upstream of the entrance to the gorge.
- Upstream of the powerhouse, sediment transport capacity is predicted to be lowered significantly, by about 50-55 percent for the small grain size (<1 cm) and about 85 percent for the large sediment (5 cm diameter). Material of 10 cm in diameter will not be transported. Consequently, accumulation of sediment is possible, but this is balanced by the reduced sediment input because of the presence of the dam-reservoir which traps sediment from the upper Nenskra catchment. The upstream catchment area is almost equivalent in size to that of the area between the dam and the powerhouse. Consequently, the reduced sediment transport capacity could be partially balanced by the reduced sediment load from upstream.
- The reduced transport capacity may reduce the capacity of the river to flush away any localised landslides on the steep banks. Venting of the sediment from the reservoir is expected to be required in later years (see Section 4.6 and Part B below).
- The slope of the river upstream of the dam is steeper than that downstream. Consequently, the contribution of solid material from the upper catchment to the sediment bedload is not as high as the contribution of the intermediate catchment between the dam and Chuberi.
- The riverbed is protected with a layer of boulders (15 cm to 30 cm in diameter). Consequently, the reduction of solid material from upstream would probably have no impact in terms of possible erosion due to a lack of solid transport from upstream. The river bed armouring will not be destroyed easily by future floods whose peak flow and frequency will be reduced by the presence of the reservoir.

Taking into account the above conclusions, it is recommended to monitor the longitudinal profile of the Nenskra River – see section 6.3.2.

B. Case of sediment venting – downstream from the dam

Venting of the sediment from the reservoir is expected to be required in later (see Section 4.6). The venting will require that the reservoir water level is lowered to the level of the bottom outlet gate at a period of the year when flood events are expected. The gate is opened during the flood event to allow the flood waters to flush out sediment. Sediment which is flushed into the Nenskra downstream of the dam may accumulate in the reach immediately downstream from the dam, but will be subsequently progressively transported further downstream by the river and when spillage of reservoir water via the spillway occurs during wet years. Venting of sediment could affect fish spawning areas and it is important for venting not to be performed during fish spawning periods. Fish spawning is understood to be in the October – November period, and flood events are most frequently in the June – September period. Recommendations regarding the best time for sediment venting are discussed in Vol. 4 Biodiversity Impact Assessment.

Table 25 – Mean monthly sediment transport load in Nenskra River – with and without dam

NENSKRA RIVER		january	february	march	april	may	june	july	august	september	october	november	december
Current state at power station	discharge (m3/s)	7.0	6.6	8.9	25.3	52.5	62.3	58.1	37.6	23.6	16.1	11.8	8.9
	maximal diameter transported (cm)	0.06	0.06	0.07	0.10	0.15	0.16	0.15	0.12	0.10	0.08	0.07	0.07
Future state upstream of power station	discharge (m3/s)	3.5	3.3	4.2	10.3	20.5	24.1	22.6	14.9	9.7	6.8	5.2	4.2
	maximal diameter transported (cm)	0.05	0.05	0.05	0.07	0.09	0.10	0.10	0.08	0.07	0.06	0.05	0.05
	if D=20 cm : current period of transport	No	No	No	No	No	No	No	No	No	No	No	No
	if D=20 cm : future period of transport	No	No	No	No	No	No	No	No	No	No	No	No
	if D=20 cm: variation of capacity (%)	No one	No one	No one	No one	No one	No one	No one	No one	No one	No one	No one	No one
	if D=10 cm : current period of transport	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
	if D=10 cm : future period of transport	No	No	No	No	No	No	No	No	No	No	No	No
	if D=10 cm: variation of capacity (%)					-100%	-100%	-100%	-100%				
	if D=5 cm : current period of transport	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
	if D=5 cm : future period of transport					Yes	Yes	Yes	Yes				
	if D=5 cm: variation of capacity (%)				-100%	-85%	-82%	-83%	-92%	-100%			
	if D=1 cm : current period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=1 cm : future period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=1 cm: variation of capacity (%)	-42%	-42%	-45%	-54%	-57%	-58%	-57%	-56%	-53%	-51%	-49%	-45%
	if D=0.2 cm : current period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=0.2 cm : future period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=0.2 cm: variation of capacity (%)	-31%	-31%	-35%	-47%	-52%	-53%	-52%	-50%	-46%	-42%	-39%	-35%
Future state downstream of power station	discharge (m3/s)	23.8	26.9	30.5	33.6	59.5	62.3	53.6	61.8	22.2	16.6	13.1	23.9
	maximal diameter transported (cm)	0.10	0.10	0.11	0.12	0.16	0.16	0.15	0.16	0.10	0.08	0.08	0.10
	if D=20 cm : current period of transport	No	No	No	No	No	No	No	No	No	No	No	No
	if D=20 cm : future period of transport	No	No	No	No	No	No	No	No	No	No	No	No
	if D=20 cm: variation of capacity (%)	No one	No one	No one	No one	No one	No one	No one	No one	No one	No one	No one	No one
	if D=10 cm : current period of transport	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
	if D=10 cm : future period of transport	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
	if D=10 cm: variation of capacity (%)	No	No	No	No	60%	0%	-26%	>100%	No	No	No	No
	if D=5 cm : current period of transport	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
	if D=5 cm : future period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=5 cm: variation of capacity (%)	>100%	>100%	>100%	80%	21%	0%	-11%	119%	-14%	>100%	>100%	>100%
	if D=1 cm : current period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=1 cm : future period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=1 cm: variation of capacity (%)	>100%	>100%	>100%	29%	12%	0%	-7%	58%	-5%	3%	9%	>100%
	if D=0.2 cm : current period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=0.2 cm : future period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=0.2 cm: variation of capacity (%)	>100%	>100%	>100%	24%	11%	0%	-6%	50%	-4%	2%	7%	96%

C. Case of spillage – downstream from the dam

Spillage of reservoir water is expected to occur during wet years and probably in the month of August (See Section 5.1.1.1B). However, the maximum flow of the Nenskra with spillage is less than average monthly flow for July for natural conditions – which is the month with the highest flow. Therefore in the case of spillage, the Nenskra flow will be similar to that of the natural conditions during the months of April and September.

The increased sediment transport capacity during spillage will allow sediment from the venting of the reservoir to be transport downstream. However, as the river flow is not greater than that of the natural situation, no increased transport of larger sized solid material that could not be transport by the natural conditions are expected.

D. Solid transport in the event of flood events

Daily and peak flood flows are available from the Lakhami gauging station (period 1981-1989). For this geomorphological study, a typical flood event has been selected and studied based on expert judgment. The selected flood event is a peak flow of 160-165 m^3/s (such as that observed 21 August 1984 and 1 July 1989) and which had an average daily flow of 115 m^3/s and which corresponds to a 10-year flood.

The impact of such flows has been computed upstream and downstream of the powerhouse. It is considered that the duration of the flood is 28 hours, with 4-hour peak and the mean daily flow for the remaining 24 hours.

The results are as follows:

- For the baseline situation, a 30 cm diameter boulder can be transported by the flow of 165 m^3/s (4-hour peak flood) but not by the flow of 115 m^3/s. The 115 m^3/s flow can transport material of <25 cm diameter;
- For the case with the dam, for the same flood event, upstream of the powerhouse material of 30 cm diameter will not be transported by the peak flow. Downstream of the powerhouse, such material can be transported and with an increased transport capacity. Protective layers of the riverbed are not expected to be destroyed downstream of the powerhouse by flood events if it consists of material >30 cm in diameter. However, the protective layer of the riverbed could be destroyed by a strong flood in the same way that is would be for the natural conditions without the dam;
- Upstream of the powerhouse, material of 20 cm diameter can be moved by both peak flood and mean daily flow for both the baseline situation and the situation with the dam. However, with the dam, the transport capacity is decreased upstream of the powerhouse by 80 percent and increased by 100 percent downstream of the powerhouse;
- Riverbed armouring could be destroyed downstream of the powerhouse, during flood events if it comprises solid material <20 cm in diameter. However, this is also the case without the dam.
- For 10 cm diameter solid material, upstream of the powerhouse and in Chuberi, the transport capacity is decreased by 35-40 percent and increased by 30 percent downstream of the powerhouse;
- For the 5 cm diameter gravel, upstream of the power plant and in Chuberi, the transport capacity is decreased by 25 percent and increased by 20 percent downstream of the powerhouse;
- For the 1 cm gravel, upstream of the power plant and in Chuberi, the transport capacity is decreased by 20 percent and increased by 17 percent downstream of the powerhouse, and

- For the 1 cm gravel and 0.2 cm sand, upstream of the power plant and in Chuberi, the transport capacity is decreased by 20 percent and is increased by 17 percent downstream of the powerhouse.

In conclusion, the behaviour during the floods in terms of bedload sediment transport will be similar to the behaviour observed for the mean monthly flows (see 6.2.1.1 A). Downstream of the powerhouse there is a transport capacity with the potential to cause erosion of the riverbed protective material <20 cm in diameter – however, the riverbed is armoured with boulders >20 cm in diameter and so erosion is probably unlikely. There is a possibility of accumulation of material <10 cm in diameter upstream of the powerhouse and in Chuberi. Consequently the conclusions made for the normal operation also apply for the flood situations and are described in section 6.3.2.

6.2.1.2 Changes to the Nakra riverbed load capacity

A. Predicted change immediately downstream of Nakra diversion

The changes to the Nakra riverbed and load capacity downstream of the diversion weir have been studied taking into consideration the predicted changes in hydrology and in particular the mean monthly flow rates for the baseline situation (without weir) and the future situation (with river diversion). The predicted changes in riverbed load capacity immediately downstream of the intake are presented in Table 26.

Table 26 – Changes to Nakra River load capacity immediately downstream of diversion

Characteristic	Baseline situation	Situation with river diversion*
Transport of gravel of 0.2 cm diameter	Transported in the months of April – September	Transported in the months of April – September (but reduced by 75% capacity compared to baseline situation)
Transport of gravel of 1 cm diameter	Transported in the months of April – September	Transported in the months of April – September (but reduced by 85% capacity compared to baseline situation)
Transport of gravel of 5 cm diameter	Transported in the months of April – September	Cannot be transported
Transport of boulders of 10 cm in diameter	Transported in the months of May – August	Cannot be transported
Largest solid material that can be moved	Material with a diameter of 12-14 cm is transported in the months of May, June, July and August	Maximal size of material that can be transported is 4-5 cm diameter,
Transport of boulders of >20 cm in diameter	Not transported by the average monthly river flows at any time of year. Can be expected to be transported during flood events;	

* Actions to maintain sediment transport function as described in section 4.8 not taken into account

The general trend downstream of the Nakra water intake will be that of sedimentation. Sediment larger than 1 cm in diameter will not move. Only flood events will have the capacity to move the sediment and the frequency of venting by floods will be significantly reduced by the river diversion, which has a maximum capacity of 45.5 m^3/s.

Table 27 – Mean monthly sediment transport load in Nakra River – with and without diversion

NAKRA RIVER - UPSTREAM LEKUERARI CONFLUENCE		january	february	march	april	may	june	july	august	september	october	november	december
Actual upstream Lekuerari	discharge (m3/s)	2.7	2.6	3.0	8.5	17.2	22.3	23.2	16.2	9.4	6.2	4.5	3.3
	maximal diameter transported (cm)	0.06	0.06	0.07	0.09	0.13	0.14	0.14	0.12	0.10	0.08	0.07	0.07
Future downstream Lekuerari	discharge (m3/s)	1.5	1.5	1.5	2.1	2.9	3.4	3.5	2.8	2.1	1.8	1.7	1.5
	maximal diameter transported (cm)	0.05	0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.05
	if D=20 cm : current period of transport	No	No	No	No	No	No	No	No	No	No	No	No
	if D=20 cm : future period of transport	No	No	No	No	No	No	No	No	No	No	No	No
	if D=20 cm: variation of capacity (%)	No one	No one	No one	No one	No one	No one	No one	No one	No one	No one	No one	No one
	if D=10 cm : current period of transport	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
	if D=10 cm : future period of transport	No	No	No	No	No	No	No	No	No	No	No	No
	if D=10 cm: variation of capacity (%)					-100%	-100%	-100%	-100%				
	if D=5 cm : current period of transport	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
	if D=5 cm : future period of transport	No	No	No	No	No	No	No	No	No	No	No	No
	if D=5 cm: variation of capacity (%)				-100%	-100%	-100%	-100%	-100%	-100%			
	if D=1 cm : current period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=1 cm : future period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=1 cm: variation of capacity (%)	-34%	-34%	-38%	-59%	-70%	-73%	-74%	-69%	-61%	-52%	-46%	-40%
	if D=0.2 cm : current period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=0.2 cm : future period of transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	if D=0.2 cm: variation of capacity (%)	-31%	-31%	-35%	-47%	-52%	-53%	-52%	-50%	-46%	-42%	-39%	-35%

B. Predicted changes upstream and downstream of the Lekverari confluence

The Lekverari is a major tributary of the Nakra River, it is situated immediately upstream of the Nakra village and provides a significant inflow of water, but also significant solid material.

The longitudinal profile slope of the Nakra River upstream of the Lekverari confluence is 0.04 and the river width is similar to the width near the Nakra diversion. Therefore, the same river cross-section shape has been adopted to compute the impact of the diversion upstream of the Lekverari confluence.

The results for changes in transport capacity upstream and downstream of the confluence are presented in Table 28.

Table 28 – Changes to Nakra River load capacity upstream & downstream of Lekverari confluence

Characteristic	Baseline situation	Situation with river diversion*
Transport of gravel of 0.2 cm diameter	Transported in the months of April – September	Transported in the months of April – September (but reduced by 50% capacity compared to baseline situation)
Transport of gravel of 1 cm diameter	Transported in the months of April – September	Transported in the months of April – September (but reduced by 60-70% capacity compared to baseline situation)
Transport of gravel of 5 cm diameter	Transported in the months of April – October	Cannot be transported
Transport of boulders of 10 cm in diameter	Transported in the months of May – August	Cannot be transported
Largest solid material that can be moved	Larger grain sediment transported in May, June, July and August Largest material transported is 12-14 cm diameter	Larger grain sediment transported in May, June, July and August Largest material transported is 7 cm diameter
Transport of boulders of >20 cm in diameter	Not transported by the average monthly river flows at any time of year. Can be expected to be transported during flood events;	

* Actions to maintain sediment transport function as described in section 4.8 not taken into account

The computation predicts that with the reduced flow in the Nakra River, only small gravel and sand with a diameter <1 cm will be transported downstream from the diversion weir to the Lekverari confluence, and consequently there will be an accumulation of sediment between the diversion weir and the confluence with the Enguri. This is described in Section 6.2.2B below, and recommendations for management of the accumulated solid material are provided in Section 6.3.

The planned Nakra ecological flow will not be able to transport downstream solid material that enters the Nakra by the Laknashura and Lekverari tributaries. The ecological flow will not have the capacity to transport material from small lateral bank landslides on the Nakra. Only flood events will have the capacity to flush sediment downstream – and the frequency of floods is expected to be significantly reduced as the diversion transfer tunnel will also deviate flood waters of a flow <45.5 m^3/s.

6.2.2 Consequences of long-term changes in sediment transport

Considering the predicted sediment transport changes, the long-term and short-term geomorphological evolution is expected to be as follows:

A. Nenskra River

- Probable accumulation of sediment between the dam and the power plant;
- Possible erosion of the riverbed downstream from the powerhouse, but considered unlikely, and
- Possible erosion of the riverbanks downstream of the powerhouse.

B. Nakra River

- Probable accumulation of sediment between the diversion weir and the entrance to the gorges downstream from the Nakra village;
- Probable accumulation of significant amounts of sediment at the Laknashura confluence;
- Probable accumulation of significant amounts of sediment at the Lekverari confluence, and
- Probable accumulation of sediment at specific points caused by a localised landslide in reaches where steep banks are present.

6.2.3 Consequences of sediment accumulation and flooding events

6.2.3.1 Sediment accumulation

A. Nenskra River

- As is the case without the Project, there is a possibility that a temporary natural dam could be created immediately downstream of the Nenskra dam caused by the naturally occurring transport of solid material by the right bank torrent. As part of the Project, the torrent is diverted to the reservoir, but during flood events there is a risk that the torrent resumes its natural path and debris flows could flow into the Nenskra downstream of the dam. The reduced Nenskra flow will represent a reduced capacity to flush away any such blockages or sediment accumulations. Monitoring and corrective actions for this type of event are described in section 6.3.1.3A and section 6.3.2.
- As is the case without the Project, creation of natural dams could be formed occasionally at some points along on the Nenskra caused by small local landslides on steep high banks. The reduced Nenskra flow will represent a reduced capacity to flush away any such blockages or sediment accumulations. The area where this is most likely to occur is near the hamlet of Kari between Chuberi and Tita. There is a small crossing the river, which at that point is in a narrow gorge and the banks in the zone are steep and unstable. Monitoring and corrective actions for this type of event are described in section 6.3.1.3B.

B. Nakra River

- As is the case without the Project, temporary natural dams could be created occasionally (in the order of once every 10 years) at the Laknashura and Lekverari confluences as a result of a debris-flow or mudflow events along the tributaries. The reduced Nakra flow will represent a reduced capacity to flush away any such blockages or sediment accumulations.
- As is the case without the Project, creation of natural dams can be formed at some points along on the Nakra caused by small local landslides on steep high banks. The reduced Nakra flow will represent a reduced capacity to flush away any such blockages or sediment accumulations.

In order to mitigate the impact described above, the Project Company has made a commitment [WAT 9] – see page 47. The Project Company will ensure that periodically the natural river flow will be reinstated to allow accumulated sediment from the reach downstream from the weir to be carried downstream. This will be undertaken on an as needed basis, including the case of situations when landslides on tributaries have caused (or threaten to cause) blockage of the Nakra.

6.2.3.2 Flood risk

A. Nenskra River

- For the reach between the dam and the powerhouse, with the Project the likelihood of flooding is decreased compared to the situation without the dam. This is because the dam-reservoir will “absorb” the peak flow when the reservoir is not at maximum operating level at the time the flood event occurs.
- The average daily flow rates of flood events between the dam and powerhouse for the situation with the dam will be reduced by 45.5 m^3/s (because of turbining) compared to the natural flood situation when the reservoir is at maximum operating level. However, if there is no turbining at the powerhouse during the flood event the flow rate will be almost the same as for the natural conditions without the dam – though slightly lower as the reservoir will naturally attenuate the peak flood flow rates.
- Downstream of the powerhouse, for most flood events the river flow is expected to be the same as for the natural situation without the dam for the same flood event - though slightly lower as the reservoir will naturally attenuate the peak flood flow rates.
- The detailed project design studies will include the definition of the worst case scenario for an operational malfunction occurring during a flood event and resulting in an incremental increase in river flow compared to the flood event alone. Flood modelling will be undertaken to define the extent of any flooding that could occur in the Nenskra valley.

B. Nakra River

- The physical presence of the Nakra diversion weir and transfer tunnel should protect the Nakra village from the more frequent smaller flood events, as the transfer tunnel will deviate part of the flood waters (45.5 m^3/s) to the Nenskra reservoir.
- As is the situation without the Project, occasional temporary blockage of the Nakra could occur. The temporary blockage could occur because of the accumulation of solid material transported by the Lekverari and Laknashura tributaries and would occur at the confluence between the Nakra and the tributaries. If any such natural dam where to be created, upstream communities would be exposed to flooding, and when the dam bursts because of the hydraulic load of river water retained – downstream communities would be exposed. However, it is not possible to quantify this risk. Accumulation of sediment in the Nakra River as a result of the reduced flow and solid transport capacity could increase the likelihood of creating a natural dams. However, the reduced flow in the Nakra could change the temporal aspects of any such event – and the upstream flooding and rupture of the temporary dam would take longer than for the situation without the dam with an equivalent flood event.

In order to mitigate the risk described above, the Project Company has made a commitment [WAT 9] – see page 47.

6.3 Mitigation strategy and monitoring program

6.3.1 Mitigation measures

Map 6-1 illustrates the situations addressed by the proposed mitigation strategy.

6.3.1.1 Measures to manage Lekverari sediment

There are two sediment issues on the Nakra River: (i) solid material originating from landslide events and resulting mudflows in the Lekverari catchment which have caused temporary blockages of the Nakra immediately upstream of the Nakra village (see §3.1.3.1), and (ii) reduced sediment transport capacity of the Nakra as a result of the Project. Consequently, to manage the accumulation of sediment from the Lekverari torrent, the commitments with regard to maintaining the Nakra sediment transport function ([WAT 9] see section 4.8.2B) will be implemented. The commitment include design features, functions and operation of the Nakra diversion weir and transfer tunnel to allow regular flushing by re-established the natural flow of the Nakra River for certain periods. The commitments also include carrying out specialist studies with respect to improving the understanding of baseline sediment situation, and establishing recommendations for (i) sediment flushing flow rates, frequency and duration, (ii) sediment accumulation monitoring and (iii) evaluation of the need for and concept of river maintenance works.

6.3.1.2 Measures to manage sediment from the Laknashura River

The Laknashura torrent further upstream from Nakra villages presents similar risks to that of the Lekverari in terms of blocking the Nakra due to sediment transport and landslide on lateral banks. The accumulation of sediment will be managed as for the Lekverari torrent described above.

6.3.1.3 Measures to manage Nenskra sediment

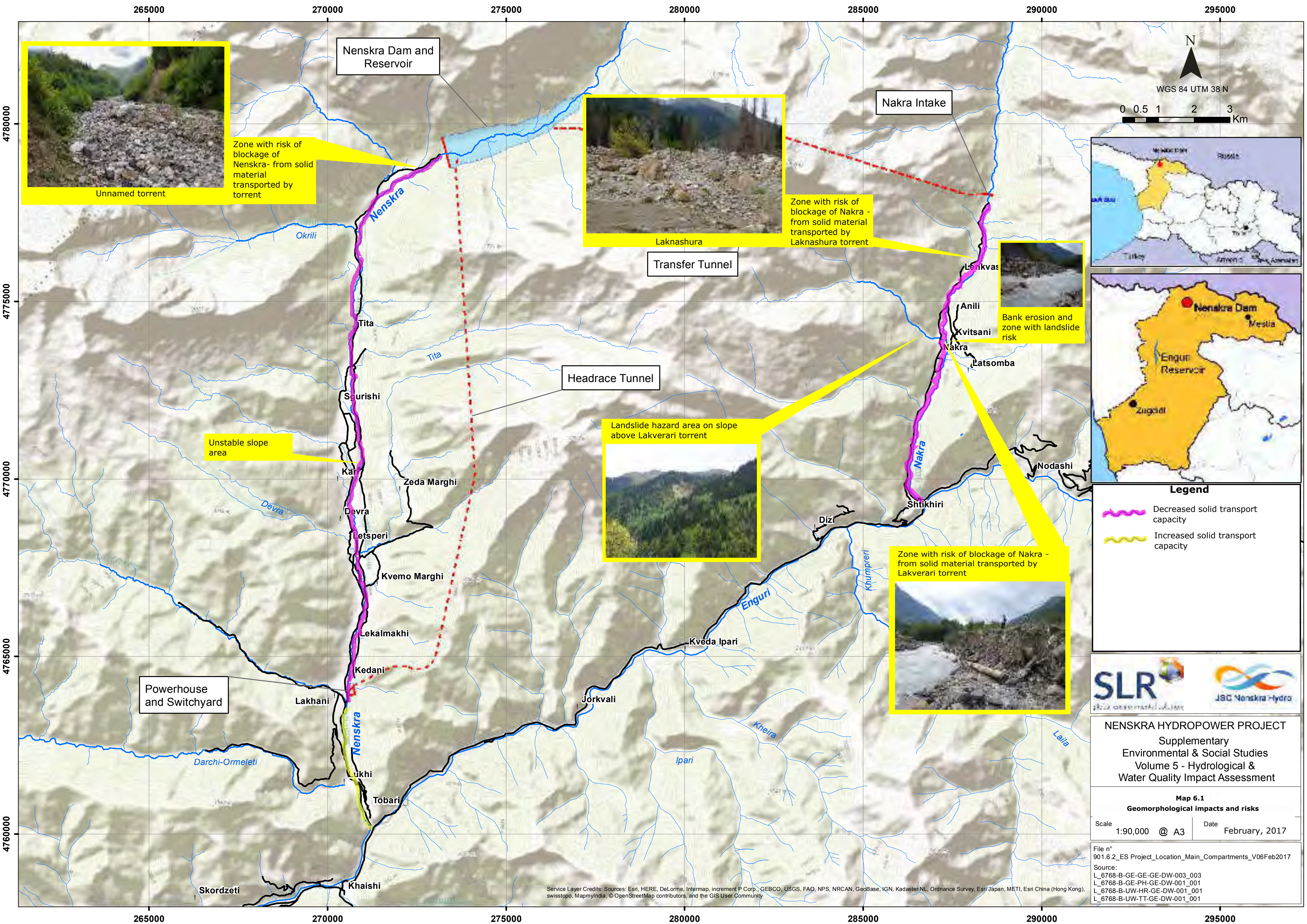
A. Reach immediately downstream from the dam

Any such build-up of sediment downstream from the dam – originating from debris flow events on the right bank directly downstream from the dam - hindering river flow and causing the creation of water retaining dams (see section 6.2.3.1A) should be easily observable from the dam and corrective action will be taken. In addition annual monitoring will be undertaken. Corrective actions could comprise re-diverting the right hand bank torrent flow directly to the reach downstream, opening briefly the dam's bottom outlet gate – or reverting to mechanical excavation.

B. Unstable slopes near Kari

There is a risk of solid material accumulation and blockage in the Nenskra riverbed caused by lateral landslide on a steep high slopes above the river near the hamlet of Kari (see section 6.2.3.1B). A specialist study will be carried out to improve the current understanding of the risk, and establish the mitigation measures, and corrective actions in the event of landslide. A road used by local communities – but not Project traffic – crosses the unstable area and the road will be included in the scope of the specialist study. This measure is referred later in this report as:

[WAT 22] Specialist study with regard to the evaluation and control of unstable Nenskra river bank slopes near the village of Kari.


Nenskra Dam and Reservoir
Nakra Intake
Transfer Tunnel
Headrace Tunnel
Powerhouse and Switchyard
Zone with risk of blockage of Nenskra- from solid material transported by torrent
Unnamed torrent
Laknashura
Zone with risk of blockage of Nakra - from solid material transported by Laknashura torrent
Bank erosion and zone with landslide risk
Landslide hazard area on slope above Lakverari torrent
Zone with risk of blockage of Nakra - from solid material transported by Lakverari torrent
Unstable slope area
Nenskra
Okrili
Tita
Devra
Nakra
Enguri
Khumpreri
Kheira
Ipari
Laila
Darchi-Ormeleti
Tita
Sgurishi
Kari
Zeda Marghi
Devra
Letsperi
Kvemo Marghi
Lekalmakhi
Kedani
Lakhani
Lukhi
Tobari
Khaishi
Skordzeti
Jorkvali
Kveda Ipari
Dizi
Shtikhiri
Nodashi
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WGS 84 UTM 38 N
0 0.5 1 2 3
Km
Nenskra Dam
Mestia
Enguri Reservoir
Zugdidi
Legend
Decreased solid transport capacity
Increased solid transport capacity
SLR
JSC Nenskra Hydro
NENSKRA HYDROPOWER PROJECT
Supplementary Environmental & Social Studies
Volume 5 - Hydrological & Water Quality Impact Assessment
Map 6.1
Geomorphological impacts and risks
Scale 1:90,000 @ A3
Date February, 2017
File n° 901.6.2_ES Project_Location_Main_Compartments_V06Feb2017
Source:
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6.3.2 Monitoring programme

The geomorphological assessment has identified that because of predicted changes in sediment transport in the Nenskra and Nakra Rivers there may be long-term changes to the geomorphology of the riverbed downstream of the Nenskra reservoir and downstream of the Nakra diversion weir. Consequently the Project will implement a geomorphological monitoring program of the two rivers through (i) annual visual survey of the rivers to identify possible landslides and/or strong solid transport and deposition at the main tributaries confluences, and (ii) topographical survey of the longitudinal water level profile at low water. This measure is referred later in this report as:

- [WAT 23] Geomorphological monitoring of the two rivers.

The best parameters for the geomorphological monitoring of the rivers will be:

- An annual visual survey of the rivers to identify possible landslides and/or strong solid transport and deposition at the main tributaries confluences, on:
  - The reach of the Nakra River extending from the water intake and to a point downstream of the Nakra village, and
  - The reach of the Nenskra River between the dam and a point about 1 kilometre downstream of the power plant.

- Topographical surveys of the longitudinal profiles of the rivers for a known lower water level flow rate:
  - Nakra River: at least from 1 kilometre upstream of the Lekverari confluence up to 1 kilometre downstream of this confluence, first survey before works, then with a periodicity of 5 years, after dam construction, and
  - Nenskra River: between 400 metres upstream of the Chuberi main bridge and 1 kilometre downstream and between 500 metres upstream of the power plant and 500 metres downstream.

The surveys will be undertaken every 5 years, to monitor any changes in the riverbed, in particular to identify if sedimentation is observed upstream of the powerhouse and if erosion is observed downstream of the powerhouse – including erosion of the riverbed armouring. The first survey is to be undertaken before the dam construction starts. Specific monitoring of the torrent located immediately downstream from the dam on the right bank and which will be diverted in the reservoir is to be carried out. It is possible, taking into account the size of the alluvial fan, with various branches, that the diversion channel will not divert all flow, and some of the flow could be discharged into the Nenskra River immediately downstream of the dam – and a build-up of solid material will be created. This deposit would not be flushed away naturally and the current design of outflow from the bottom outlet is downstream of where such a deposit could be created. If any such deposits form they could be cleared using mechanical shovels.

During the first year of operation there will be monthly monitoring of the condition of the banks of the Nenskra along the reach immediately downstream from the powerhouse and extending to the gorge 2 kilometres downstream. In subsequent years the monitoring will be quarterly then annually if no erosion is observed. If erosion is observed in zones where there is a threat of flooding areas affecting the road, people's homes or areas of economic importance, then the banks will be reinforced using suitable means. This measure is referred later in this report as:

- [WAT 24] Monitoring of Nenskra River banks conditions downstream of powerhouse. Strengthening as and when required.

7 Impact on water quality

7.1 Assessment methodology

The assessment of water quality encompasses the prediction of water quality in the future Nenskra reservoir after reservoir filling and how the water quality is expected to evolve over time with the operation of the dam-reservoir. Resulting impacts on the Nenskra River water downstream of the dam are evaluated and impacts on the Nakra River water quality downstream of the transfer tunnel diversion weir are also evaluated.

The predicted water quality is evaluated in terms of nutrient and inorganic concentrations, Dissolved Oxygen (DO) concentration and water temperature. Concentrations of nutrients, inorganics and DO have been estimated using a quantitative approach and using worst case assumptions. For the evaluation of temperature a qualitative approach has been used.

One of the concerns of reservoir water quality for dam projects in general is that the quality can be modified by high nutrient loading causing eutrophication, algal blooms, reduction in DO concentration, and changes in pH. The assessment has therefor included an evaluation of the risk that these types of impacts could occur for the Nenskra reservoir.

The quantities of flooded biomass and soils have been used to estimate the quantity of nutrients and inorganics that could potentially be released into the Nenskra reservoir water. Nutrients that have considered comprise Nitrogen (N), Phosphorous (P), and Organic Carbon. Inorganics comprise Calcium (Ca), Magnesium (Mg), and Potassium (K). The concentrations in the reservoir water have been estimated using reservoir recharge rates. The nutrient concentrations are compared to values reported in literature for reservoirs of different trophic classification, thus indicating the possible trophic classification of the Nenskra reservoir.

Nutrients and inorganics that enter the reservoir originate from the flooded biomass, soils and to a much lesser extent from the reservoir inflow. Conservative estimates of the kinetics of the input into the reservoir water have been estimated.

The reservoir operation comprises a cycle of filling and then emptying the reservoir over the period of each year of operation – and this effectively is a process which flushes out the nutrients and inorganics that have accumulated in the reservoir. The concentrations in the reservoir water have been estimated on a yearly basis over 30 years and are seen to fairly rapidly decrease because of the flushing effect.

The estimated concentrations of organic carbon in the reservoir water – released from flooded biomass, soil and inflow – is used to estimate the concentrations of DO in the water. It is assumed that the organic carbon is converted to carbon dioxide in an aerobic biodegradation process, releasing carbon dioxide, consuming the DO in the reservoir water and lowering the DO concentration in water. It is also assumed that the DO in the reservoir will be lowered as result of the residence time in the reservoir and temperature. The evolution of the DO in the reservoir over 30 years has been estimated.

The temperature of the reservoir water has been estimated qualitatively by considering the reservoir operation – the cycle for filling and emptying the reservoir, the period when the reservoir is full, and the origin and temperature of the relative flow rates of inflow.

7.2 Uncertainty and sensitivity

There is a high degree of confidence regarding the calculations to estimate (i) the quantity of biomass in the area to be inundated and (ii) the quantity of nutrients and inorganics that are present in the flooded biomass. There is also a high degree of confidence regarding the quantity of inorganics transported into the future reservoir by the Nenskra and Nakra Rivers.

However, there is some uncertainty regarding the rate of biodegradation of the flooded biomass. Consequently, there is some uncertainty with respect to the concentrations of nutrients and inorganics in the reservoir water and how many years are necessary for the nutrients and inorganics to be flushed from the reservoir by the reservoir filling and emptying cycles – which are part of the normal operation.

To address the uncertainty, 2 biodegradation rates for soft biomass have been used to calculate nutrient and inorganic concentrations in the reservoir water. The 2 rates used are considered to represent the “fastest” and “slowest” credible rates. There is a high degree of certainty that the actual rate of biodegradation in the reservoir will be situated in the range between the 2 rates used. Consequently there is a high degree of confidence that the predicted concentrations of nutrients and inorganics in the reservoir water and downstream river water will be in the range of the results predicted for the 2 cases. The 2 biodegradation cases are described in section 7.4.2.4.

In terms of sensitivity, the soils contain the majority of the nutrients and inorganics which will enter the reservoir water. The rate with which these are released to the reservoir water is the factor which has the greatest influence on the results of the calculations. Case 1 biodegradation rate is for a high rate of release to ensure that this contribution to reservoir water is not minimised.

7.3 Assumptions on reservoir vegetation clearing

It is assumed that vegetation present in the reservoir inundated area will be cleared prior to reservoir filling. All trees will be removed and understory vegetation, i.e. shrubs and ground flora, will also be cleared as far as is technically possible without exceeding excessive cost. The clearing of vegetation is undertaken because the amount of flooded vegetation influences both GHG emissions and reservoir water quality.

The reservoir impoundment area covers 260 hectares of which 158 hectares are woodland and the remaining land cover includes river and associated gravels, grassland, landslide areas and scrub. The river and associated gravels correspond to areas earmarked as borrow areas. The location of borrow areas within the reservoir footprint and the areas to be cleared of vegetation are presented on the map provided in Figure 13.

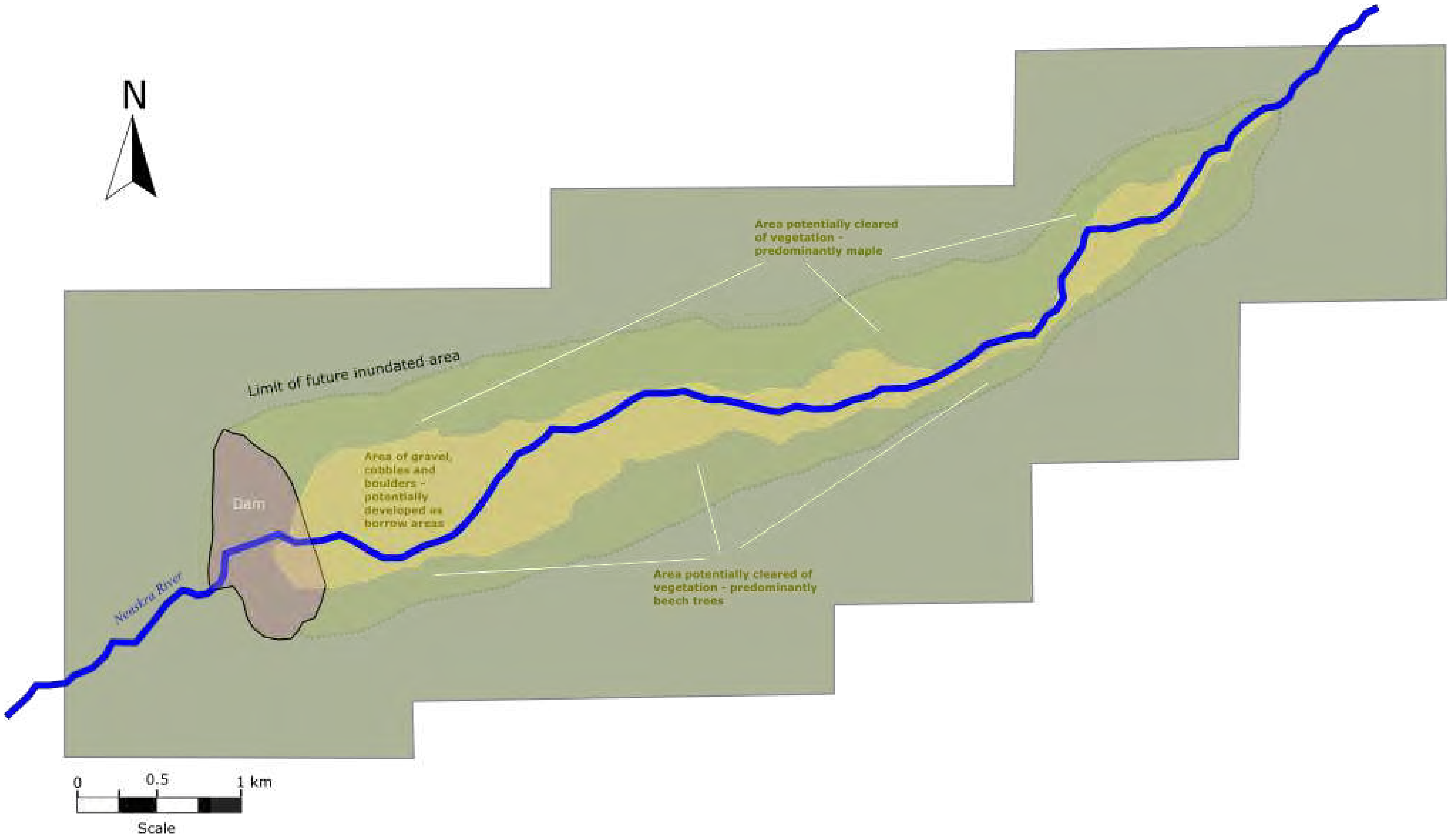


Figure 13 – Reservoir footprint, borrow areas and areas cleared of vegetation

7.4 Assessment of impacts on reservoir water quality

7.4.1 Typical factors affecting reservoir eutrophication

The major water quality issue for dam-reservoirs is that of the creation of eutrophic conditions, which is the excessive development of primary and secondary producers (algae, macrophytes, zooplankton) resulting in oxygen depletion and algal blooms. Eutrophication of reservoir consequently affects downstream water quality. The creation of eutrophic conditions is presented in the schematic provided in Figure 14.

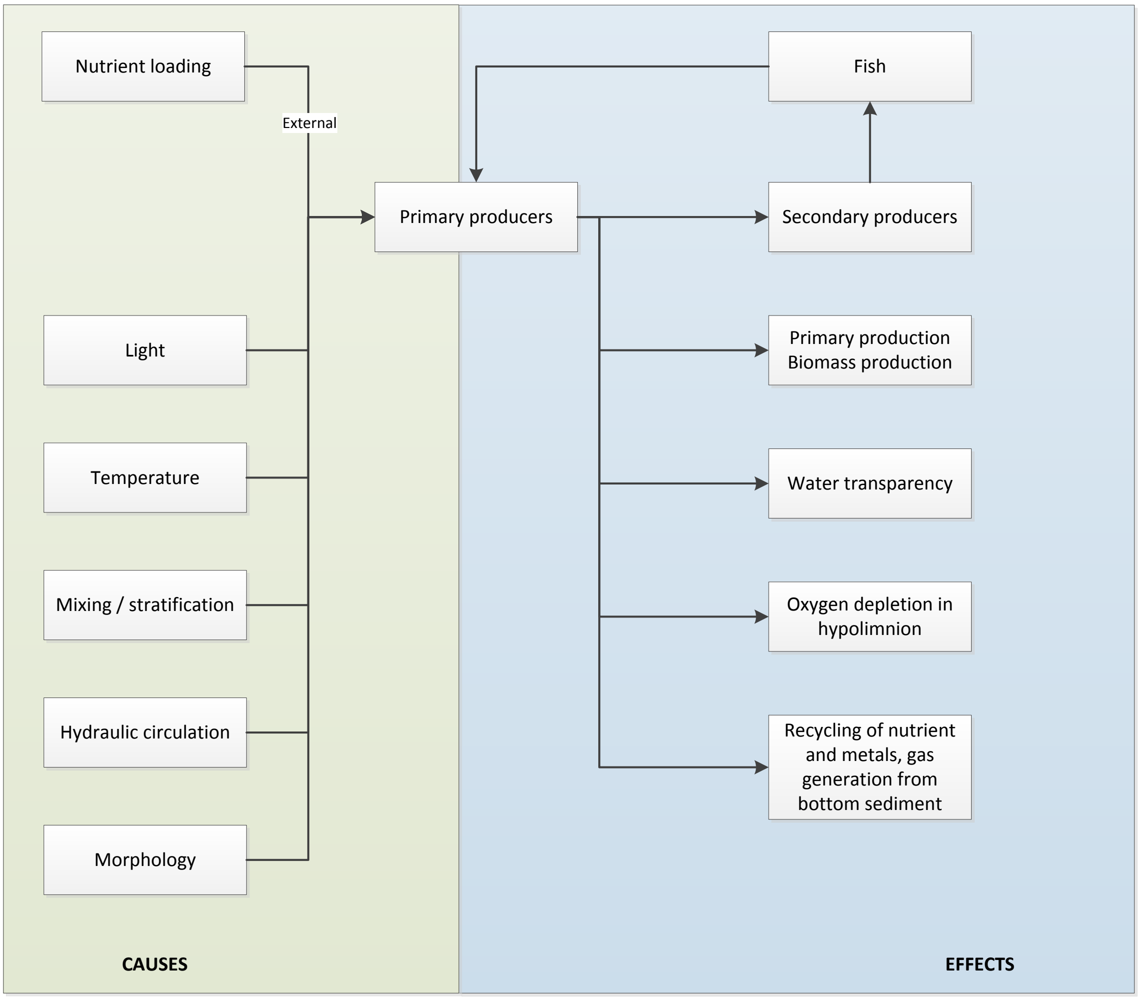


Figure 14 – Cause and effect of eutrophication schematic

Source: Chapman, 1996

The main factors that influence the creation of eutrophic conditions include the following;

- Inflow water quality, in particular the presence of presence of nutrients especially phosphorus and organic compounds. An inflow of nutrients and organic matter at sufficiently high levels can be favourable for creation of eutrophic conditions in the reservoir. Inflow water quality is influenced by the land cover and land us of the upstream drainage basin;

- Water storage residence-time – the longer the water is stored the higher the chance of changes in water temperature and if sufficient nutrients are present the creation of eutrophic conditions;
- Water depth, geometric form of the reservoir and reservoir operation. These aspects can be the cause of the creation of thermoclines and zones of stagnant anioxic water;
- Biomass in the inundated area, the biodegradation of the biomass and the release of nutrients to the reservoir water can cause eutrophic conditions, and
- Nutrients and organic matter in the flooded soils will be released over time into the reservoir water and if sufficiently high levels are produced in the water, eutrophic conditions can be produced.

7.4.2 Predicted vulnerability of Nenskra reservoir to eutrophication

7.4.2.1 Inflow water origin and nutrient content

The Nenskra reservoir receives inflow water from the catchment basins of both the Nenskra and Nakra Rivers. Both these catchment basins are characterised by the limited anthropogenic activities, and this is reflected in the baseline quality of the river water. The in-situ and laboratory analysis indicates that the waters are of pristine quality and typical of small unpolluted mountain rivers/streams.

There are no industrial activities and limited artisanal or agricultural activities in the dam-reservoir catchment basin. Local people from the Nenskra valley move small numbers of cattle to the upland areas including parts of the dam-reservoir catchment areas during the summer months, and there is some limited artisanal tree cutting/lumber activities. However, there appears to be no discernible effect on water quality from these activities.

The catchment area is very homogenous and water qualities of the different tributaries feeding into the Nenskra and Nakra upstream of the future dam-reservoir are thought to be much the same in terms of physical-chemical characteristics.

In terms of nutrients, the river waters have very low total organic carbon and phosphorus concentrations. Nitrates, nitrites, sulphates, phosphates concentrations are below detection limits or very low. Consequently the inflow does not have the characteristics favourable for creating reservoir eutrophication.

7.4.2.2 Reservoir form and flow through the reservoir

The reservoir is 5 kilometres in length and has a regular shape, there are no islands, and although there are some small bays formed at minimum operating level, the shape is generally of a form that should optimise the unhindered flow or water through the reservoir without forming areas of stagnate water. The geometric form of the reservoir is present in Figure 15.

The reservoir volume at maximum operating level is 176 million cubic metres, and at minimum operating level the volume is 14.5 million cubic metres. The reservoir has an annual recharge of 816 million cubic metres of water, which represent 4.64 times the full capacity of the reservoir. There is consequently a high recharge rate. The water level at maximum operating level is at an elevation of 1,430 metres asl, and at an elevation of 1,340 meters asl. The reservoir longitudinal and cross section profiles are provided in Figure 16. These schematics illustrate that at minimum operating level, 92 percent of the water has been drained from the reservoir leaving only 8 percent of the water. This operating mode, with high recharge rate minimises the risk of creating areas of anioxic stagnant water.

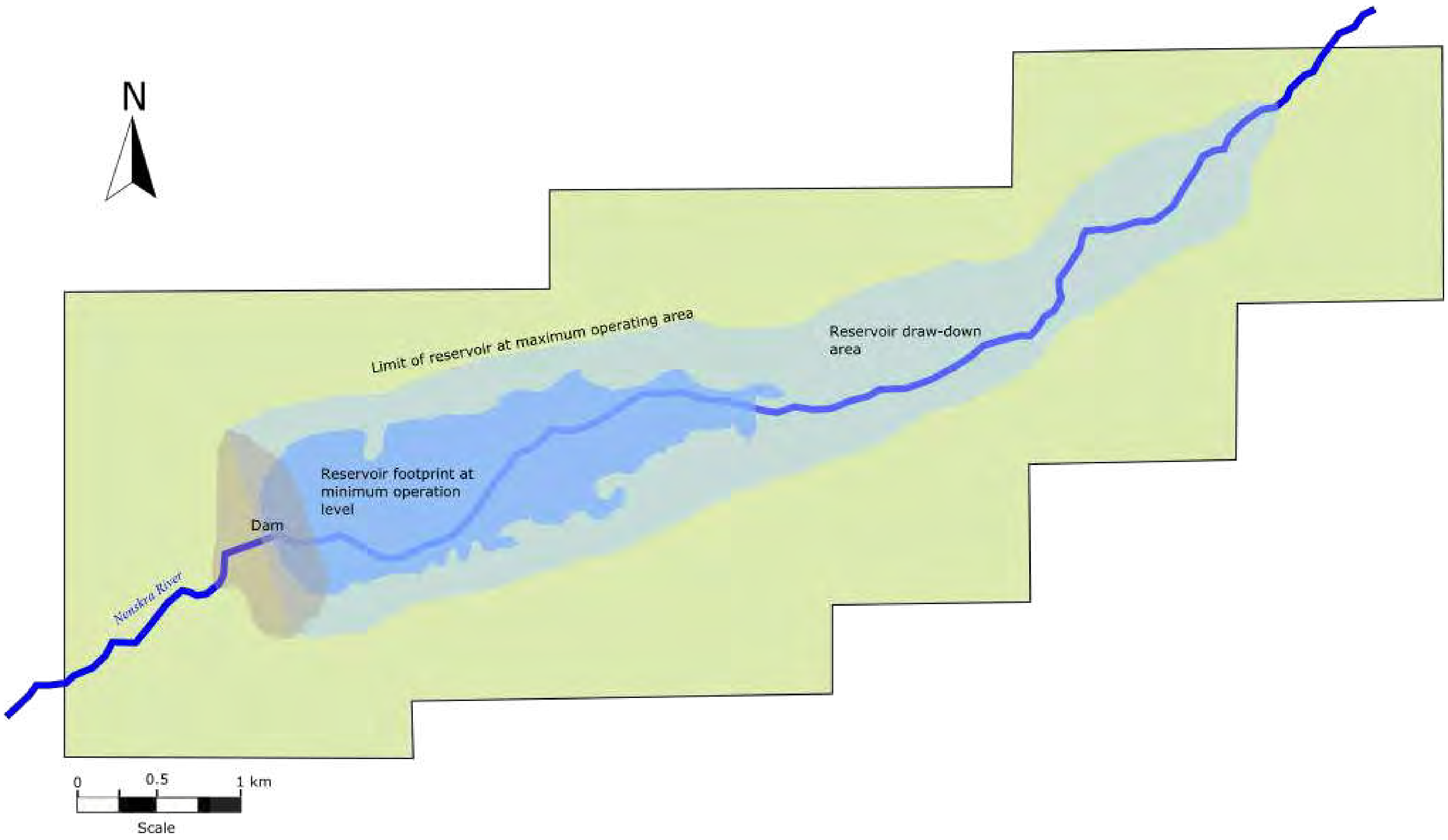


Figure 15 – Geometric shape of reservoir at maximum and minimum operating levels

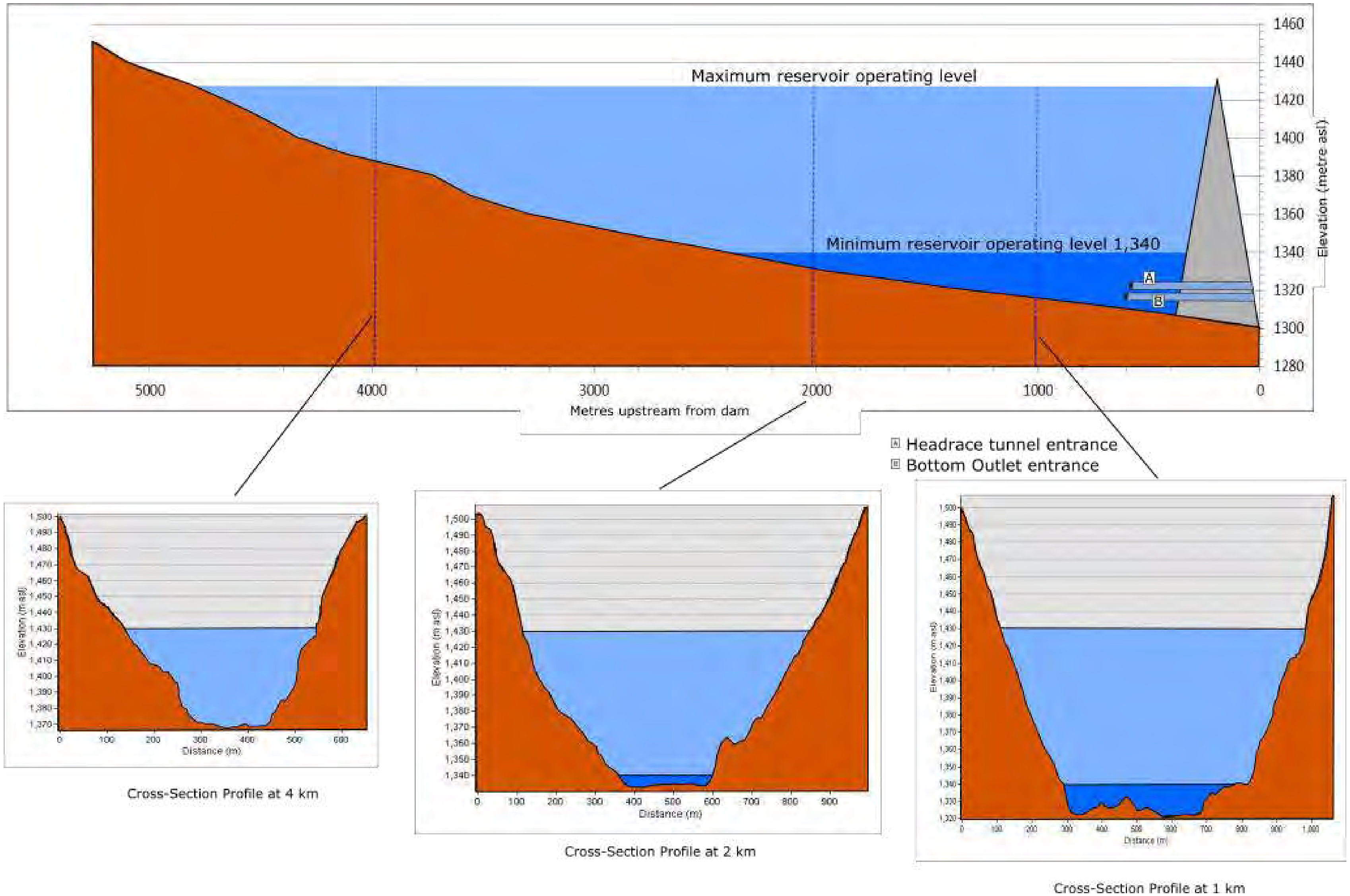


Figure 16 – Reservoir longitudinal and cross-section profiles

7.4.2.3 Nutrients in vegetation and soils in the inundated area

The quantity of biomass in the inundated area has been estimated in order to estimate the quantities of nutrients that could potentially be released into the reservoir water and which would affect water quality. The amount of carbon material is also estimated so that GHG emissions can be estimated. Vegetation present in the inundated area will be cleared prior to flooding as described in §7.3, and consequently nutrient input is predominantly from flooded soils and to a much lesser extent from biodegradation of the understory vegetation (shrub layer and ground flora) which cannot technically be removed.

The assumptions and approach used in the calculations are outlined as follows:

- All trees will have been cleared prior to reservoir filling.
- Although most shrubs and ground flora shall be removed as part of the vegetation clearing, the calculation takes a precautionary approach and includes all biomass present in the understory. This is because there is some uncertainty regarding how much of the understory vegetation can be effectively cleared, and because the amount of understory biomass is very small compared to flooded soils. Understory vegetation is estimated as a function of the above ground biomass (Annex 1 provides the estimation of aboveground biomass). It is assumed that the understory biomass is equivalent to 6.8 percent of the above ground biomass (Gonzalez et al, 2012)[4].
- The reservoir operation will create an important draw down area each year. It is not expected that vegetation will grow on the drawdown area and contribute to further degrading of the water quality when the reservoir refills. This assumption is made because it can be seen that no vegetation grows on the Enguri reservoir drawdown area, which is at a lower altitude than the Nenskra reservoir and which also has an important yearly fluctuation in water level.
- The quantities of organic matter and nutrients in soils have been estimated using the information that the type of soils in the inundated area is "brown mountain soil", which is reported in the Project ESIA (Gamma, 2012). However, the information on soils in the ESIA does not indicate nutrient and organic carbon content or physical properties of mountain soils. Consequently this information has been sourced through review of different scientific publications on the subject of soils in the Caucasus Mountains and which are available in the public domain. The key parameters and source used for assumptions are presented in the Table 29.

There is high degree of confidence regarding the estimated quantities of nutrients and inorganics in the biomass and soils. This is because of the area of flooded vegetation has been measured, the type of vegetation is known from field observations and values of the concentrations of nutrients and inorganics in vegetation are those reported in reliable and recognised scientific sources. Concentrations of nutrients and inorganics in soils used in the calculations are those reported in scientific publications regarding soils in the region at similar altitudes.

[4] The value of 6.8 is to be considered as an order of magnitude as the reference used for estimating this is not for forests in Caucasus Mountains. However, any errors related to this factor are expected to be negligible as the biomass from understory represents only a small fraction of the total biomass, and there is a much higher degree of certainty with respect to biomass in soils which make up the rest of the flooded biomass.

Table 29 –Nutrients and biomass in soils

Soil Parameter	Value	Source	Quantity in soils (tonne)
Area flooded	260 ha	Fichtner, 2015	---
Depth of soil	10 cm	ESIA (Gamma, 2012)	---
Bulk density	1,300 kg/m^3	Expert judgement	---
Moisture content	55%	Expert judgement	---
Nitrogen (N) content	100 g/kg	Makarov et al., 2001	15,210
Phosphorus (P) content	948 mg/kg	Makarov et al., 2004	144.2
Potassium (K) content	85 mg/kg	Onipchenko et al. 2001	12.9
Carbon I content	84 g/kg	Makarov	12,776

Biomass and nutrient in the understory have also been estimated and the amounts presented in Table 30.

Table 30 –Nutrients and biomass in understory vegetation

Parameter	Quantity (tonnes)	Parameter	Quantity
Understory biomass	1,522	Ca	4.08
N	3.8	Mg	0.62
P	0.46	Carbon	761
K	3.57		

7.4.2.4 Nutrient and organic carbon input into reservoir water

The reservoir water will receive nutrients and organic carbon, and it is this input – combined with temperature and flow characteristics, which determines the risk of eutrophication resulting in modified reservoir water quality. The nutrient input is from the following sources:

- Biodegrading of the flooded vegetation;
- Release of nutrients in the flooded soil, and
- Nutrients in the inflow (Nenskra and Nakra Rivers).

The quantities of nutrients and organic carbon in the vegetation and soils are estimated in 7.4.2.3 above. The concentrations of nutrients and organic carbon in the Nenskra and Nakra river inflow have been measured in during the water quality survey work. All concentrations were below detection limit, and as for this assessment the concentrations of the detection limit have been used as a worst case assumption.

The concentration of the nutrients and organic matter in the reservoir water is dependent on (i) the rate at which the nutrients in the soil and vegetation are released, and (ii) the rate of the flow of water through the reservoir.

There are some uncertainties regarding the rate at which nutrients in the flooded soil and vegetation are released to the reservoir water and this is discussed in section 7.2. Two cases for the rate of biodegradation are used and there is a high degree of confidence that the actual rate of biodegradation will be in within the range of the 2 cases used. The 2 cases are as follows:

- Case 1 – assumes that the biodegradation of that soft above ground biomass is 1 year, and soft biomass in soils is 6 months. This is the most credible “fast” rate of biodegradation and is considered as the case that would lead to the highest concentrations of nutrients and inorganics in the reservoir water immediately after reservoir filling. However, for this case the nutrients in biomass are also flushed from the reservoir in what is expected to be the shortest time.

- Case 2 – assumes that the biodegradation soft above ground and soil biomass is 2 years. This is the most credible "slow" rate of biodegradation and is considered as the case that would lead to the longest time for nutrients from biomass to be flushed from the reservoir.

The assumptions that have been taken in estimating the rate of release of nutrient and organic carbon are as follows:

- Biomass will biodegrade aerobically releasing carbon dioxide gas and liberating the nutrients. This assumption is adopted because the oxygen content of the inflow is saturated, the calculations have established that there is sufficient oxygen in the inflowing water to enable all biomass to biodegrade aerobically and the form of the reservoir is such that no stagnation or no (or only limited duration) thermocline is expected (see 7.4.2.2).
- Soft biomass (foliage) will biodegrade with an expediential rate of decay with time constant of between 2.9 and 1.4 years (i.e. a half-life of between 1 and 2 years). This is based on literature value (Fearnside, 1995);
- Nutrients will be released from soils with an expediential rate of release with time constant of between 8.5 months and 2.9 years (i.e. a half-life of between 6 months and 2 years). This is a conservative estimate, that is based assuming that nearly all the nutrients will be released from inundated soils within a period of 10 years of reservoir filling – and 95 percent in the first 3 years.

The quantity of water that flows through the reservoir in 1 year is 816 million cubic metres, which represents filling and emptying the reservoir 4.64 times. The concentration of the nutrients in the reservoir water is estimated to be equal to the annual amount of nutrient input (from biodegradation of soils and vegetation, and input of nutrients transported with river inflow) divided by the annual amount of water that flows through the reservoir.

The evolution of the concentration of nutrients, organic carbon and dissolved oxygen over time (with and without vegetation clearing) are presented in Figure 17.

These findings are discussed in §7.4.3.

7.4.2.5 Risk of methylmercury formation

The mercury concentration in the river water was measured as part of the water quality survey in order to establish if there is mercury input into the reservoir. The finding of the laboratory analysis is any mercury present is below detection limits (<0.05 µg/l). This is not surprising as there are limited anthropogenic activities in the upstream catchment basin. Consequently there is very low risk of the formation of methylmercury.

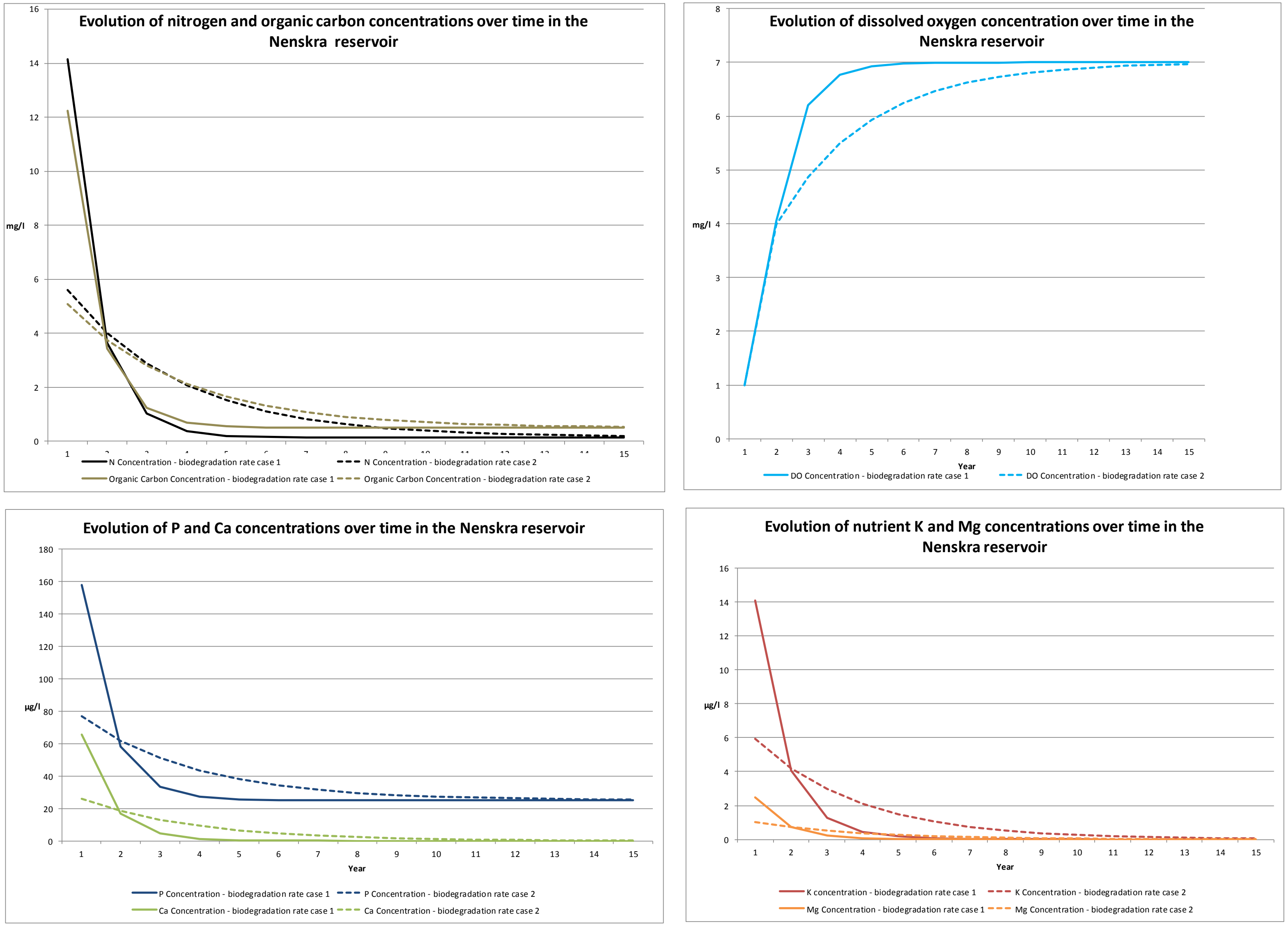


Figure 17 – Evolution of reservoir nutrient, organic carbon and DO concentrations over time after reservoir filling

7.4.2.6 Reservoir water temperature

The reservoir water temperature is estimated taking into account the origin of the inflow – i.e. glacial melt water or rainwater runoff – and the reservoir operation modes.

At the end of November of each year, the reservoir is full with water than has been collected over the period of March to November. The origin of the water during the filling period is essentially glacial melt water – as precipitation is low during this period. During the filling period the reservoir will have been maintained at maximum level since the month of August and the surface waters are expected to have been warmed by the air temperature. However, the through put of water during this filling period also needs to be considered. The total annual reservoir inflow is 816 million cubic metres. The reservoir volume (at maximum operating level) is 176 million cubic metres, i.e. reservoir recharge is equivalent to 4.64 reservoir volumes per year. The residence time is therefore approximately 3 months. Taking into consideration the above, the surface waters can be expected to have been warmed and could be in the order of 15 degrees Celsius. The water at depth – where there is mixing and a high renewal rate – will probably be of temperatures close to that of the natural river water temperature during the summer months (approximately 10 degrees Celsius).

During the period of December to February, the reservoir water level is lowered from the maximum to the minimum level. During this period there is low inflow and the water that is turbined is mainly the stored water. Although the cold inflow water will sink to the bottom of the reservoir where the headrace inlet gate is located, the water that is released from the reservoir is expected to be warmer than the Nenskra river water under natural conditions, and could be in the order of 3 to 5 degrees Celsius.

During the reservoir filling period, the water that is released from the bottom of the reservoir is composed of the cold inflow water that because of its higher density sinks to the bottom of the reservoir. Consequently during the months of March – November, the temperature of the outflow is expected to be the same as the water temperature of the Nenskra without the dam, i.e. 10 to 11 degrees Celsius.

However, during wet years (2 years out of 10), there will probably be spillage of reservoir surface water during the months of July and possible also June or August. The water evacuated via the spillway and discharged into the Nenskra will be of a higher temperature than that of natural conditions without the dam and could be at a temperature of 15 degrees Celsius compared to natural conditions in the order of 10 degrees Celsius.

The factors affecting reservoir and outflow temperature are illustrated in the schematics provided in Figure 18.

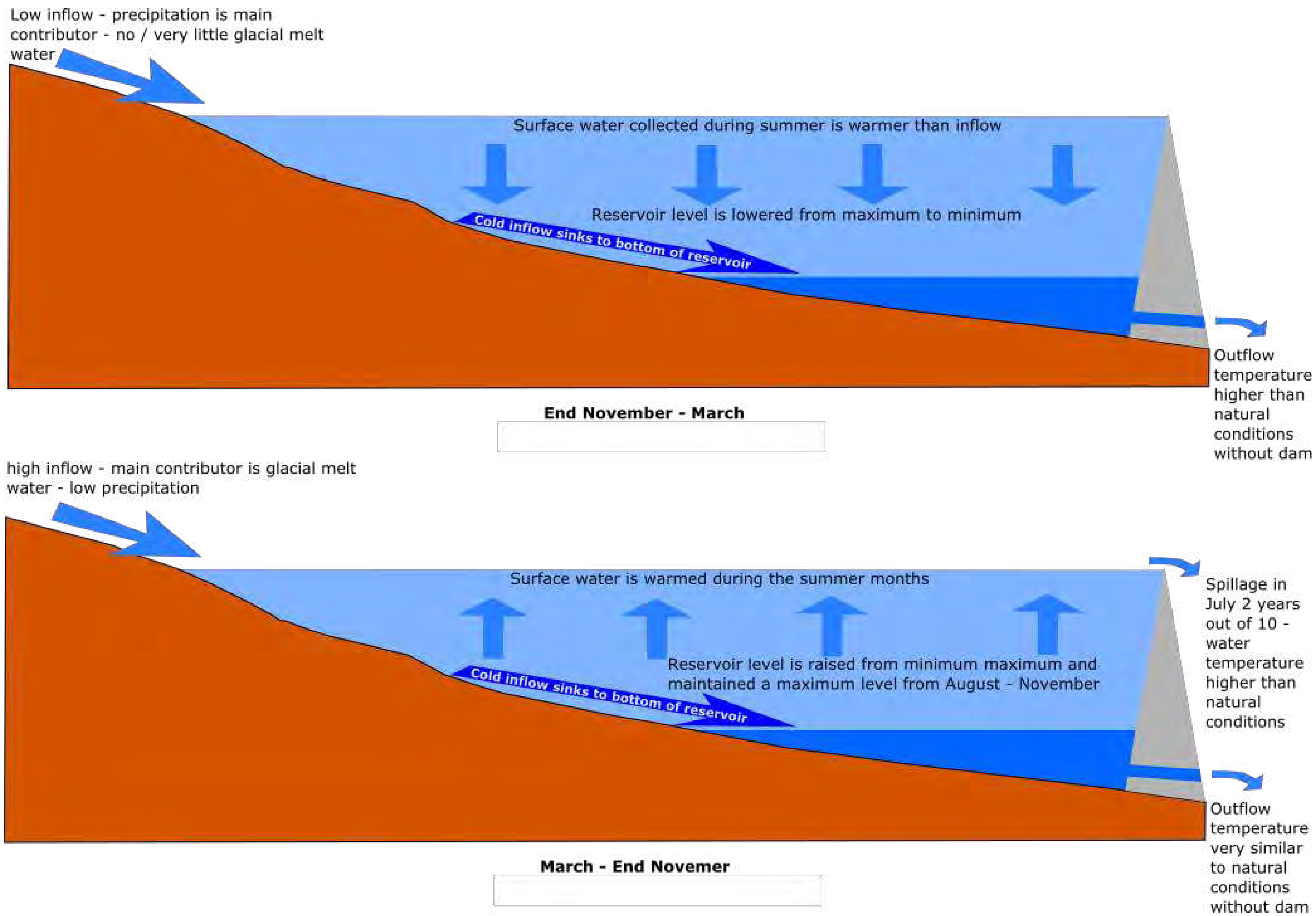


Figure 18 – Schematic illustrating factors influencing reservoir temperature

7.4.3 Discussion and conclusions

7.4.3.1 Risk of creation of eutrophic conditions

In terms of the risk of creating eutrophic conditions in the reservoir, the main factor is the nutrient loadings and in particular nitrogen (N), phosphorus (P) and the N/P ratio. For an N/P ratio > 7, P is limiting, and for a ratio <7, N is limiting.

The concentrations of N and P lakes and reservoirs of different trophic classification are presented in Table 31 below. The values in this table are used as a reference when estimating if the predicted concentrations of P and N in the reservoir water represent a risk of creating eutrophic conditions.

Table 31 – Trophic classification of lakes and reservoirs and N and P concentrations

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Average total P (µg/l)	0.8	26.7	84.4	>200
Average total N (mg/l)	0.661	0.753	1.875	High

Source: UNEP

The calculations for predicting N and P concentrations take into account (i) the rate of nutrient and inorganic input from the biodegradation of flooded biomass and (ii) reservoir inflow and outflow demonstrate that the majority of the nutrients and inorganics in the flooded biomass will have been released to the reservoir water and flushed downstream (see Figure 17).

Two cases for biomass biodegradation rates have been used in the calculations to predict N and P concentrations (see section 7.4.2.4). The predicted N and P concentrations for the 2 cases are discussed below.

A. Case 1 biodegradation rate – fast biodegradation

The case 1 biomass biodegradation rate assumes a credible fast rate of biodegradation which results in high nutrient levels in the first years after reservoir filling, but nutrients will be rapidly flushed from the reservoir (see section 7.4.2.4). The predicted concentrations of N and P in the reservoir during the first 10 years after resrevoir filling are presented in Table 32 below.

Table 32 – Predicted N and P concentrations in the reservoir – case 1 biodegradation rates

Year	1	2	3	4	5	6	7	8	9	10
P (µg/l)	158[a]	58[b]	33	27	26	25	25	25	25	25
N (mg/l	14	3.65	1.0	0.37	0.2	0.16	0.15	0.15	0.15	0.15
N/P ratio	90	63	31	14	8	7	6	6	6	6
Limiting element	P	P	P	P	P	N	N	N	N	N
Risk of eutrophic conditions	Yes	Possible	No	No	No	No	No	No	No	No

Notes:

[a] Value typical of concentration in eutrophic lakes and reservoirs – see Table 31

[b] Value typical of concentration in mesotrophic lakes are reservoirs – see Table 31

Comparing the predicted N and P concentrations (Table 32) with typical values for lakes and reservoirs of different trophic classification (Table 31), it can be deduced that during the first 5 years after reservoir filling, P is the limiting nutrient for primary production.

During the first 2 years after reservoir filling, the concentration of the P is in the order of that observed in eutrophic lakes and reservoirs and consequently the nutrient loading indicates **there is a risk of creating eutrophic conditions in the Nenskra reservoir during the first 2 years after reservoir filling**. In subsequent years the P concentration in the reservoir water will be at a concentration typically seen in mesotrophic lakes and reservoirs.

B. Case 2 biodegradation rate – slow biodegradation

The case 2 biodegradation rate (see section 7.4.2.4) assumes a slower rate of soft biomass degradation than case 1. The use of this rate predicts lower nutrient levels in the reservoir water, and that the nutrient levels in the reservoir decrease more slowly over time than for case 1. The predicted concentrations of nutrient in the reservoir water for this case are presented in Table 33.

Table 33 – Predicted N and P concentrations in the reservoir for case 2 biodegradation rates

Year	1	2	3	4	5	6	7	8	9	10
P (µg/l)	77[a]	62[a]	51[a]	43[a]	38[a]	34[a]	32[a]	29[a]	28[a]	27[a]
N (mg/l	5.6	4.0	2.9	2.1	1.5	1.1	0.8	0.6	0.5	0.4
N/P ratio	73	65	57	48	40	33	26	21	17	14
Limiting element	P	P	P	P	P	P	P	P	P	P
Risk of eutrophic conditions	Possible	Possible	Possible	No	No	No	No	No	No	No

Notes:

[a] Value typical of concentration in mesotrophic lakes and reservoirs – see Table 31

Comparing the predicted N and P concentrations (Table 33) with typical values for lakes and reservoirs of different trophic classification *(*Table 31), it can be deduced that P is the limiting nutrient for primary production and that the concentration of the P is less than those typically observed in eutrophic lakes and reservoirs but slightly greater than concentrations observed in mesotrophic lakes and reservoirs.

C. Conclusion

The actual N and P concentrations in the reservoir water will probably be somewhere within the range predicted by the calculations using case 1 and case 2 biomass biodegradation rates. Consequently it is concluded that there is a risk of the P concentrations similar to those found in eutrophic reservoirs in the first 2 years after reservoir filling. However, other factors need to be considered, notably the water temperature and the reservoir recharge. The water temperature close to 10 degrees Celsius and the high reservoir recharge rate should minimise primary production that could cause eutrophic conditions, and if eutrophication does occur it will probably occur during the summer months and affect the surface waters only. In subsequent years the N and P concentrations will be similar to concentrations in mesotrophic lakes and reservoirs.

This is to be considered as a conservative estimate as a precautionary approach has been used. It should be noted that majority of the P input into the reservoir is from the river inflow assumed to be with a P concentration of 25 µg/l – which is typical of surface waters. However, although no P was detected in the Nenskra and Nakra Rivers, the calculations have assumed a P inflow 25 µg/l as a worst case assumption. Consequently the reservoir's tropic classification could well be between oligotrophic and mesotropic.

7.4.3.2 Temperature of reservoir water

During the period of December to February the water that is released from the reservoir is expected to be slightly warmer than the Nenskra river water under natural conditions.

During the months of March – November, the temperature of the outflow is expected to be the same as the water temperature of the Nenskra without the dam, i.e. in the order of 10 degrees Celsius.

During wet years (2 years out of 10), there will probably be spillage of reservoir surface water during the months of July and possible also June or August. The water evacuated via the spillway and discharged into the Nenskra will be of a slightly higher temperature than that of natural conditions without the dam.

7.4.3.3 Organic carbon and dissolved oxygen

To conclude, the main points regarding reservoir water quality can by synthesised as follows:

- In the first 2 years following reservoir filling the reservoir water will have significantly higher concentrations of nutrients and organic matter compared to the natural river conditions. However, in the subsequent years the nutrient concentrations will decrease because of the flushing of the reservoir by the high reservoir throughput. However, there will inevitably be some primary and secondary production in the reservoir – though probably limited – and concentrations of organic matter and nutrient in the reservoir water will remain higher than the natural river water conditions.
- The temperature of the reservoir's surface waters during the period April – October will probably be slightly higher than the natural river water temperature which is in the order of 10 degrees Celsius. During the winter the reservoir will cool and probably reach a temperature close to that of the river – though possibly 1 to 2 degrees higher.
- The reservoir water will probably have a temperature gradient, with surface water slightly higher than the temperatures at the bottom of the reservoir. However, a thermocline is not expected to be created because of the high throughput. Similarly the creation of anioxic zones near the bottom of the reservoir is not expected.
- Inflow river water has a dissolved oxygen concentration in the order of 10 mg/l. In the reservoir the oxygen will be consumed by the vegetation biodegradation process and by primary and secondary production processes (expected to be limited). The dissolved oxygen concentration is therefore expected to be in the order of 7 to 8 mg/l in the first 2 years following reservoir filling and then increase progressively in the following years.
- The reservoir operation will create an important draw down area each year. It is not expected that vegetation will grow on the drawdown area and contribute to further degrading of the water quality when the reservoir refills.

7.5 Predicted water quality downstream from the Nenskra reservoir

7.5.1 Between the dam and the power house

7.5.1.1 Normal operation after reservoir filling

The assessment of the water quality downstream of the dam combines the findings of the hydrological study (see §4) and the findings of the assessment of impacts on reservoir water quality (see §7.4). During normal operation the only outflow from the reservoir into the Nenskra River between the dam and the powerhouse is the ecological flow, with a constant flow rate 0.85 m^3/s and which is released immediately downstream of the dam. The concentration of nutrient, organic carbon and dissolved oxygen in the Nenskra River between the dam and the power house has been estimated taking into account the following:

- Water quality of the ecological flow – which is the same as the reservoir water quality and which evolves with time after reservoir filling, and
- Dilution of the ecological flow by tributaries and runoff.

The dilutions of the Nenskra River for the different months of the year and at different points between the dam and the power house are illustrated in Figure 19. The Okrili tributary is located 3 kilometres downstream from the dam, see Table 5 in section 3.1.5.

The concentrations of nutrient, organic carbon and dissolved oxygen, over time taking into account dilution at different points between the dam and the power house are illustrated in Figure 19 to Figure 23 on the following pages. The graphs illustrate the predicted river water calculated using the 2 biodegradation cases considered for calculating reservoir water quality as described in section 7.4.3.1. The probable river water quality can be expected to be within the range of the case 1 and case 2 predictions.

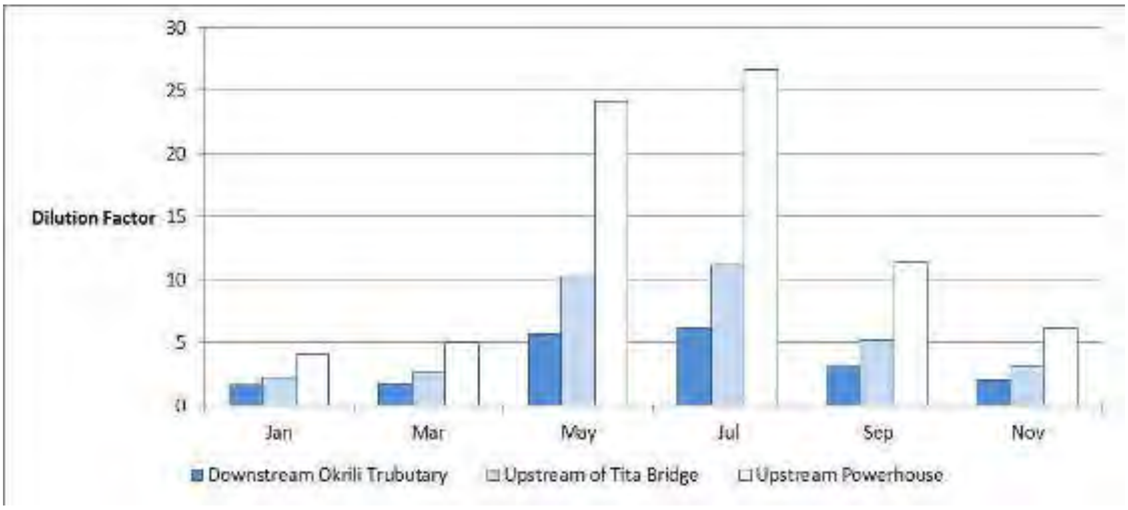


Figure 19 – Dilution factor for Nenskra River between dam and power house

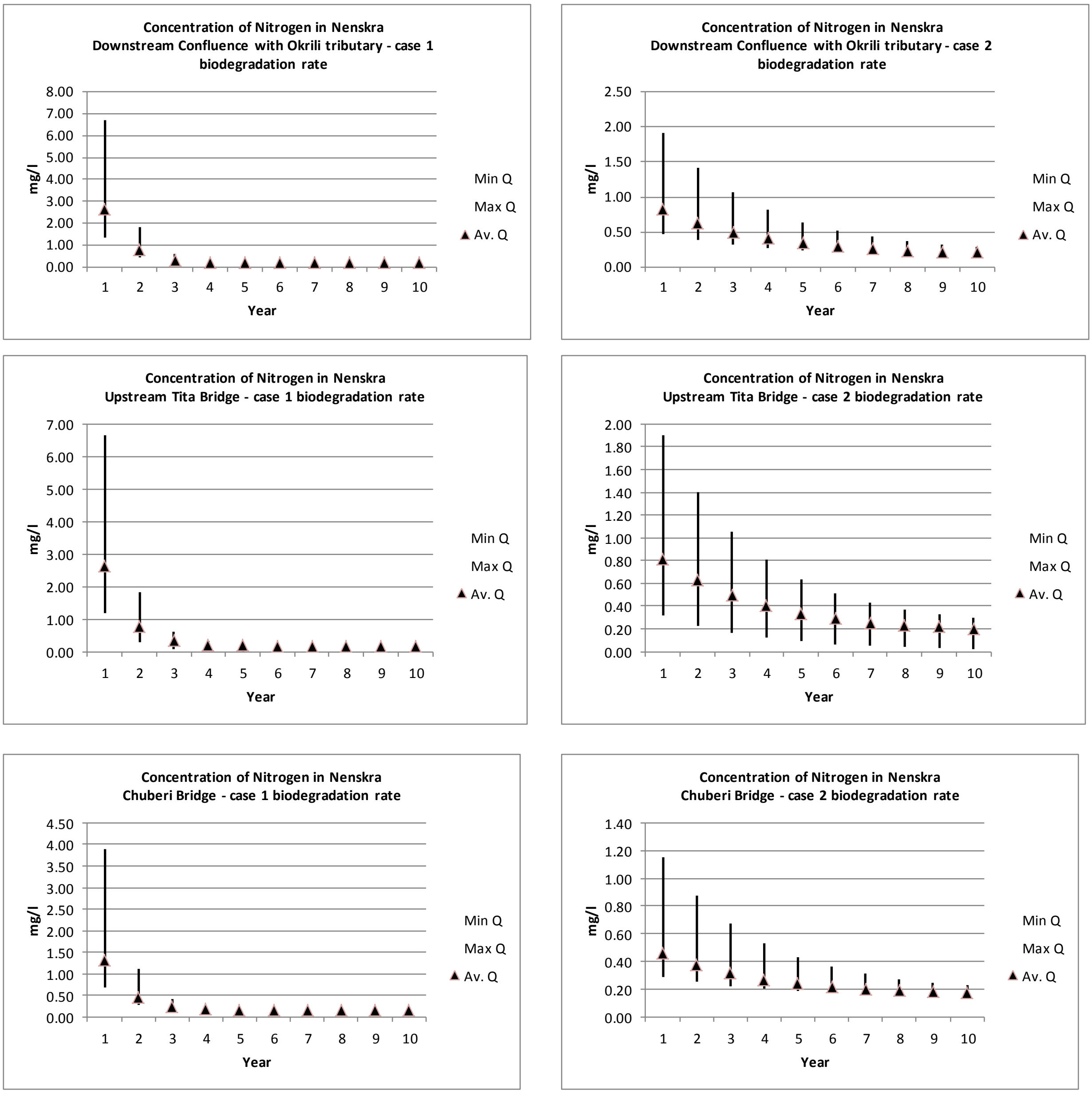


Figure 20 – Evolution over time of N in the Nenskra River between dam and powerhouse

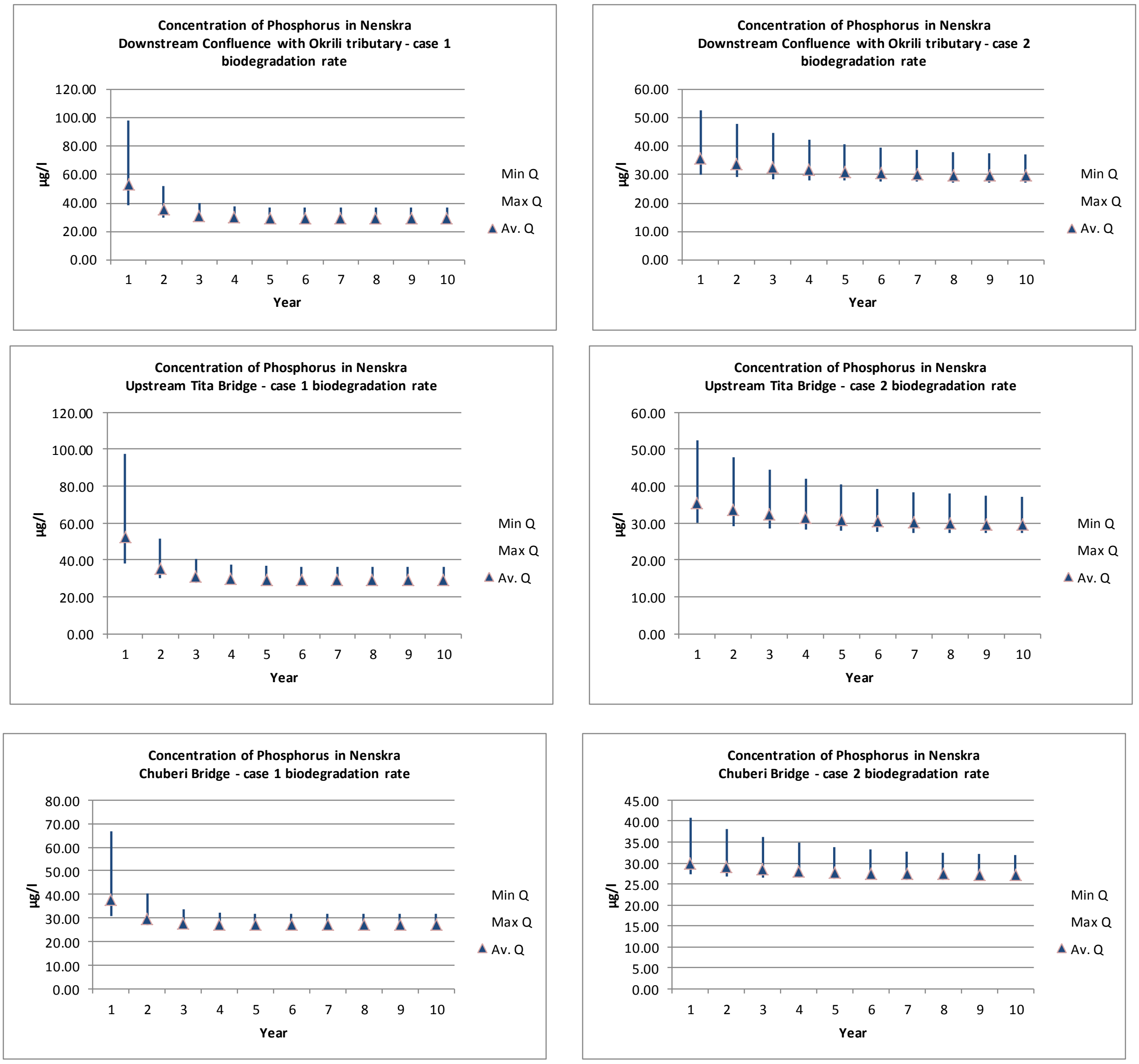


Figure 21 – Evolution over time of P in the Nenskra River between dam and powerhouse

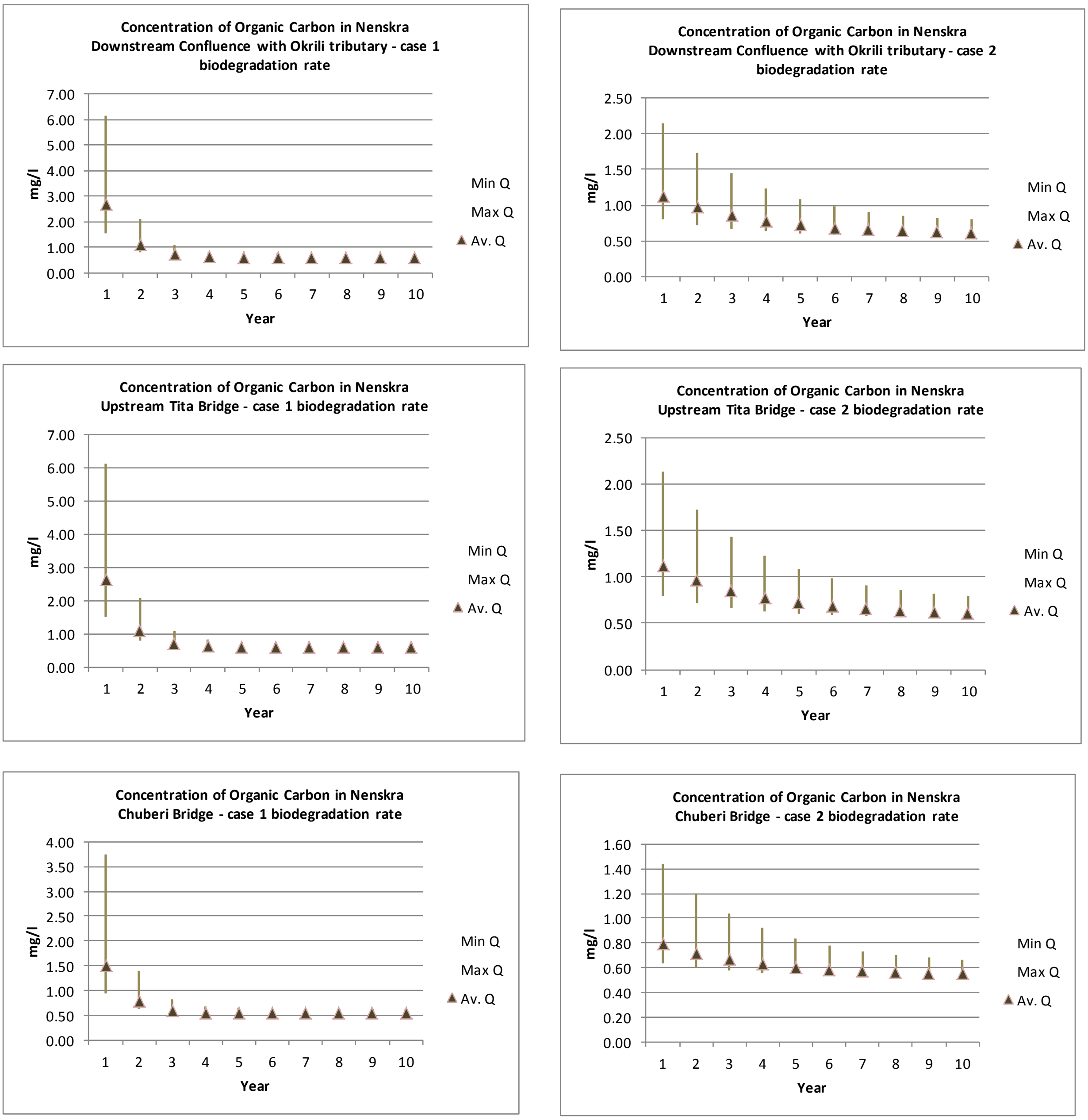


Figure 22 – Evolution over time of organic carbon in the Nenskra River between dam and powerhouse

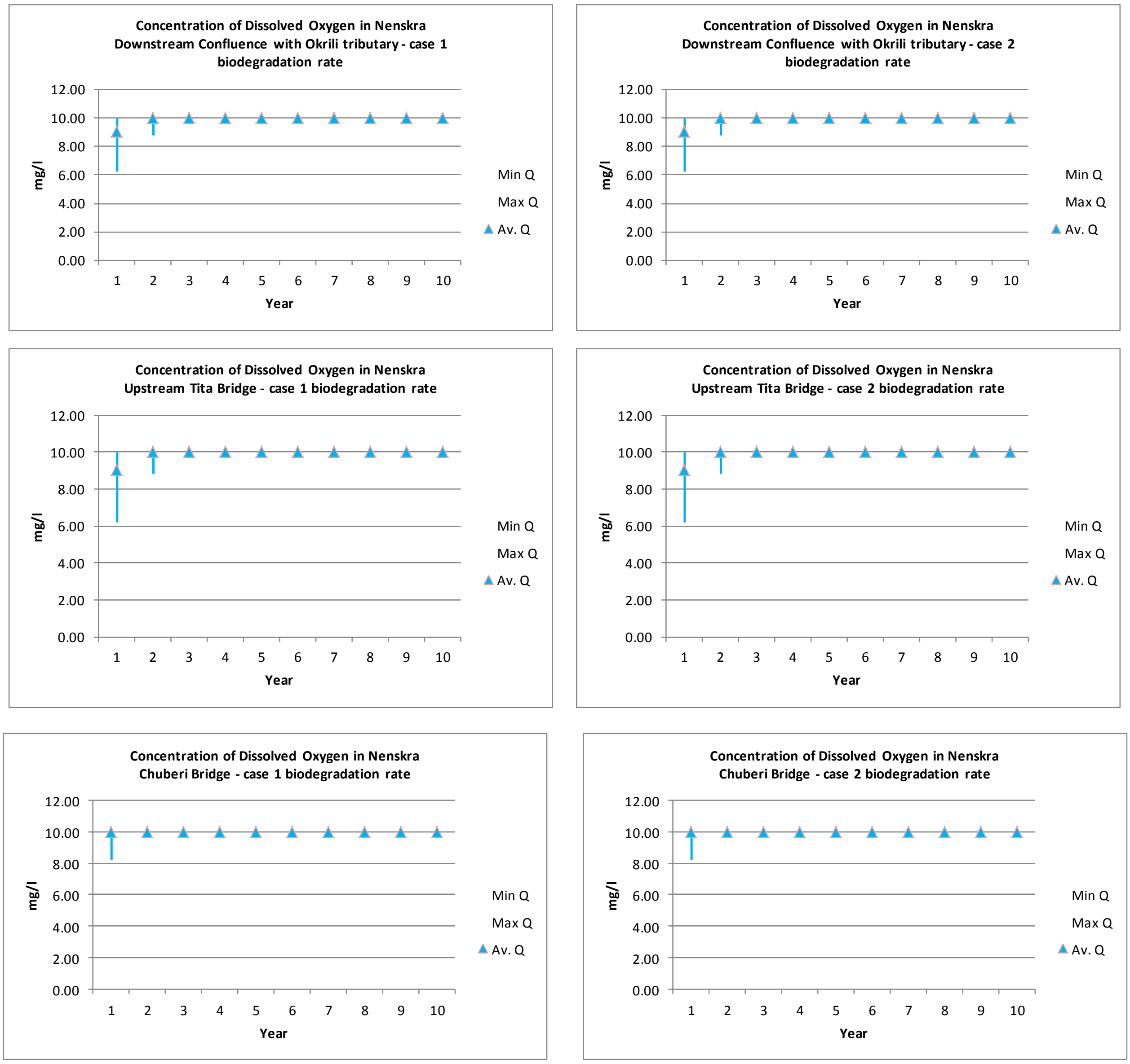


Figure 23 – Evolution over time of DO in the Nenskra River between dam and powerhouse

Figure 19 to Figure 23 on the previous pages illustrate the quality of the Nenskra river water between the dam and powerhouse over time after reservoir filling. The water quality impacts can be summarised as follows:

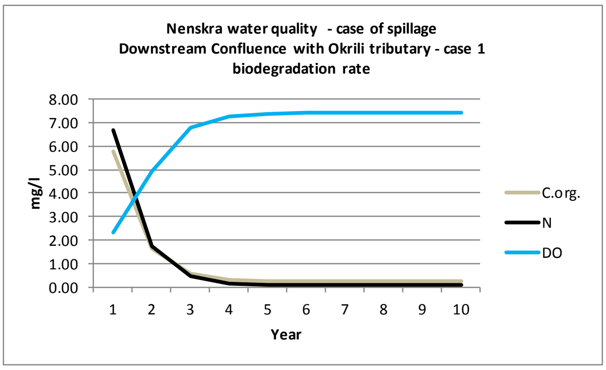
- A noticeable increase in the concentration of nutrients in the river water downstream of the dam in the first few years after reservoir filling can be expected, though the concentrations decrease between the dam and the powerhouse because of the effects of dilution. However, after approximately 3 years the reservoir water quality will have improved – as most of the nutrient input from soils and vegetation will have been flushed out – and the nutrient levels in the water will be close to those of the natural conditions.
- There will probably be a noticeable decrease in the concentration of dissolved oxygen in the river water in the river water between the dam and Chuberi in the first year after reservoir filling – as a result of decreased dissolved oxygen in the reservoir water. However, further downstream from Chuberi the change will not be noticeable due to inflow of oxygen water from tributaries, run off and the re-oxygenation of the waters because of the turbulent flow.

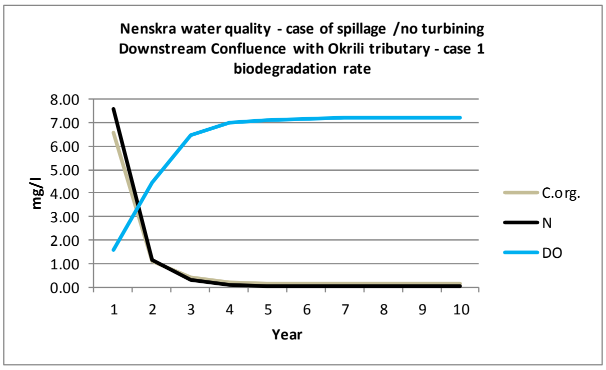
7.5.1.2 Changes in water quality due to spillage

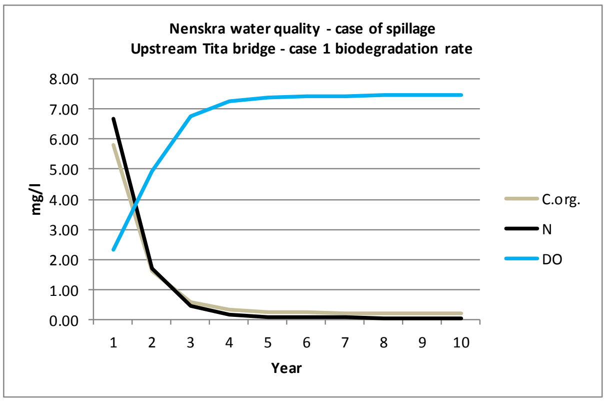
It can be expected that 2 years out of 10 will be a wet year, and there is a possibility that there will be spillage of water via the spillway See §4.5. If the spillage occurs in the first years following reservoir filling the reservoir water will be of a modified nature with low Dissolved Oxygen and high nutrient content. The spillage is expected to be of a short duration in the order of about 2 to 4 hours per day. Nevertheless the spillage is expected to cause a short term change in water quality downstream. The predicted concentrations of the nutrients and dissolved oxygen in the river water at various points between the dam and the powerhouse are presented in Figure 24 to Figure 27. The results show that the concentrations at the different points are very much the same for a given year.

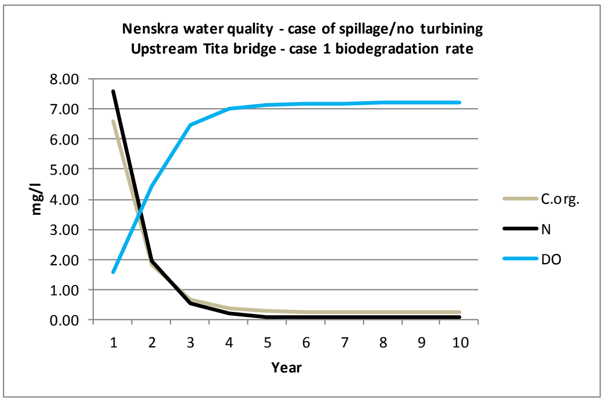
Two cases of spillage are presented: (i) the case of spillage with the powerhouse turbines in operation. The spillage rate is estimated to be typically 20 m^3/s, and (ii) the case of spillage without the powerhouse turbines in operation, which corresponds to the sum of 20 m^3/s plus the rate normally discharged by the turbines – which is 46.9 m^3/s. The spillage rate is therefore in the order of 67 m^3/s.

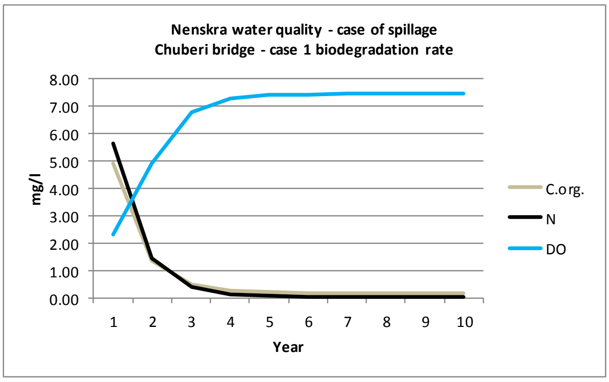
During the flood events of fairly high return periods such as between 5 and 25 year floods, the impact on water quality will be of the same order of magnitude as for the case of dam spillage described above. For more important flood events the presence of the dam and the quality of the reservoir water will not contribute significantly to effects on water quality during a flood event and in the event of flood events water quality will be much the same as for a typical year with the dam and which after 3 to 5 years will be similar to the natural conditions without the dam.











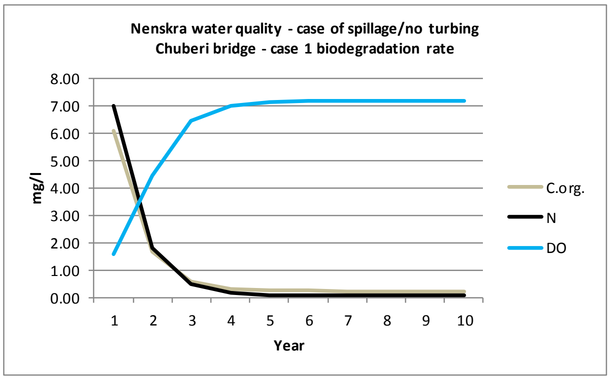


Figure 24 – Concentrations of C, N and DO in the Nenskra River between dam and powerhouse in the event of spillage – biodegradation case 1

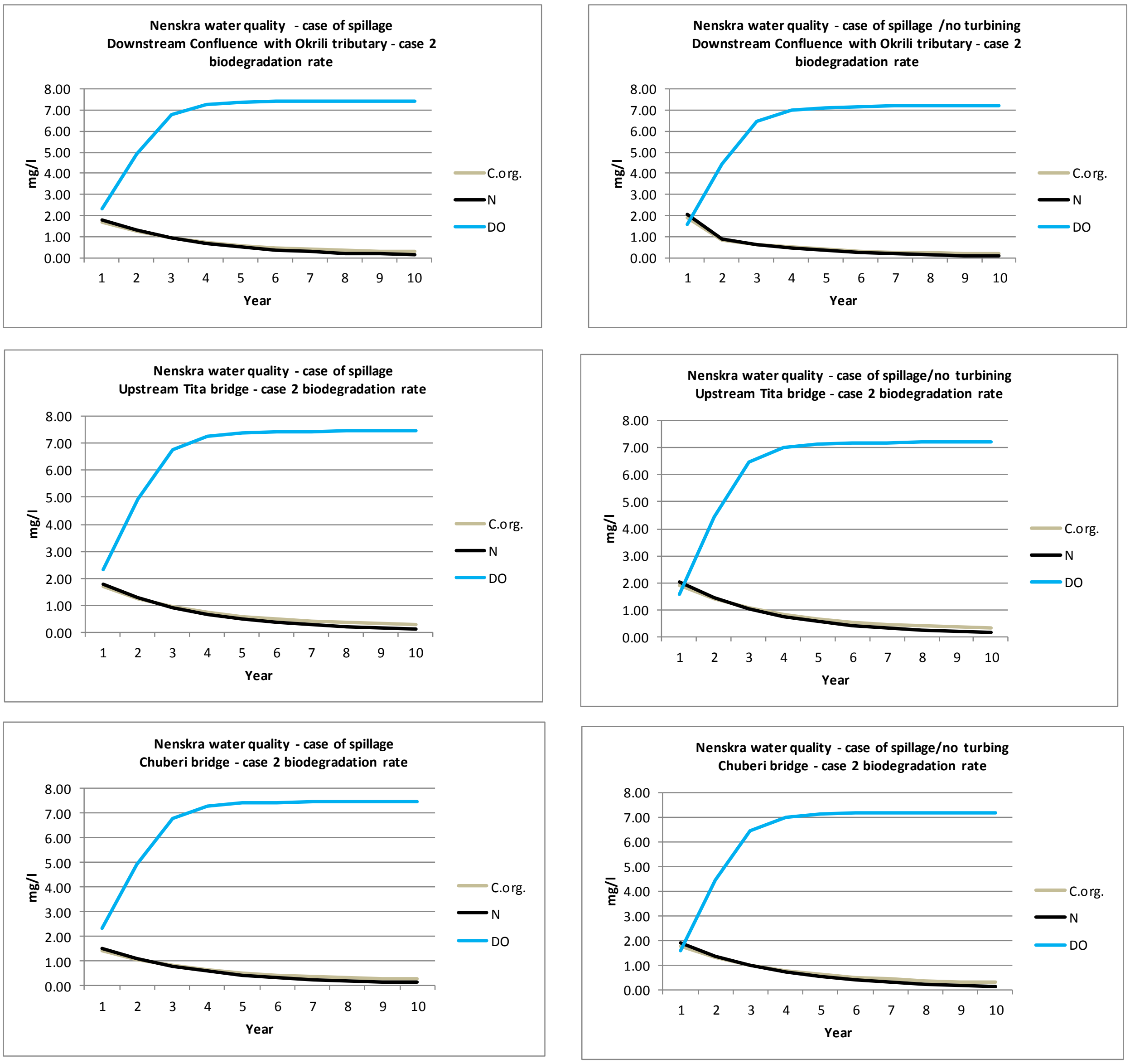


Figure 25 – Concentrations of C, N and DO in the Nenskra River between dam and powerhouse in the event of spillage – biodegradation case 2

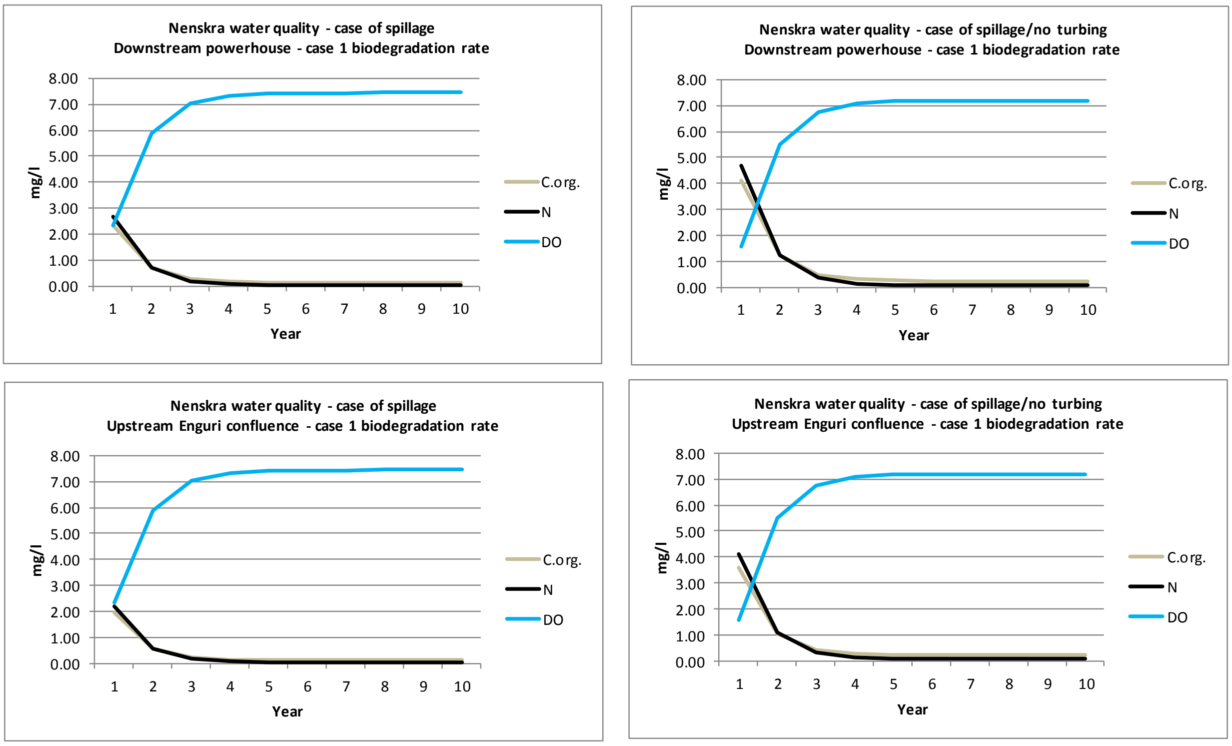


Figure 26 – Concentrations of C, N and DO in the Nenskra River downstream of the powerhouse in the event of spillage – biodegradation case 1

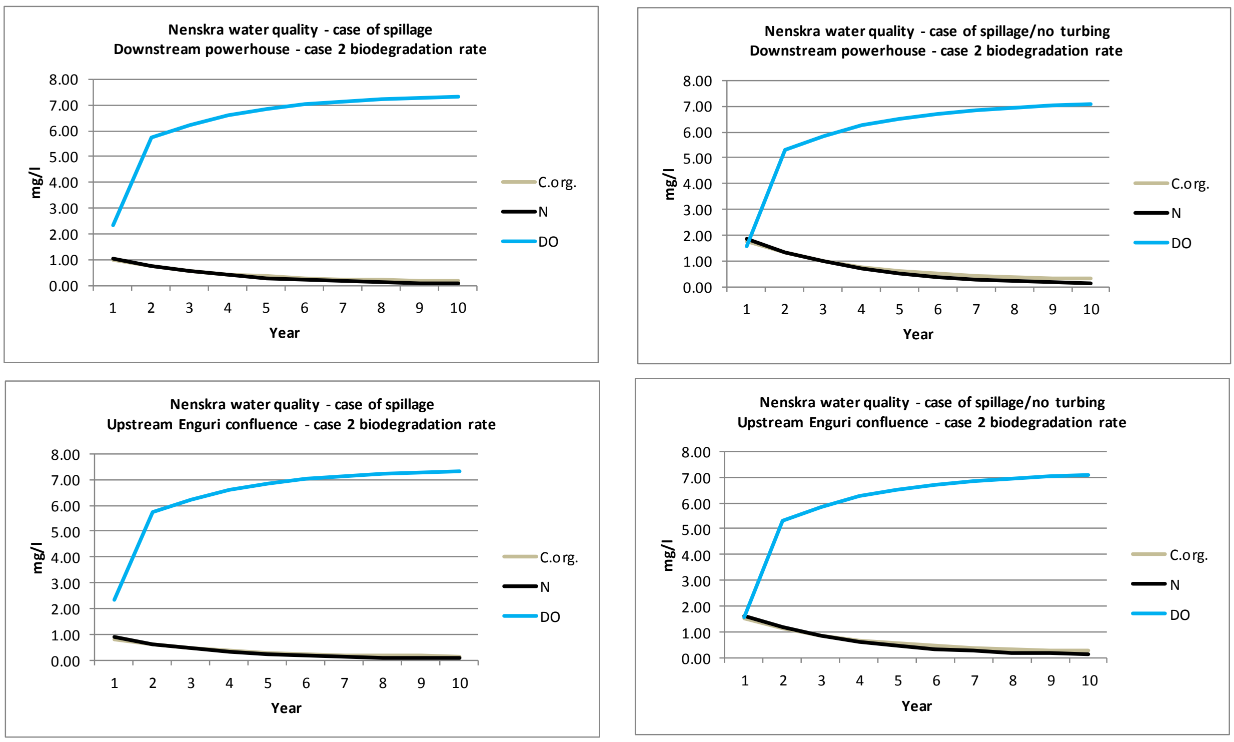


Figure 27 – Concentrations of C, N and DO in the Nenskra River downstream of the powerhouse in the event of spillage – biodegradation case 2

7.5.2 Downstream of the powerhouse: Nenskra River and Enguri River

7.5.2.1 Water quality changes after reservoir filling

The assessment of the water quality downstream of the powerhouse combines the findings of the hydrological study (see §4) and the findings of the assessment of impacts on reservoir water quality (see §7.4). The turbined water outflow from the powerhouse has a flow that is nominally in the range of 11 to 39 m^3/s, but with a maximum capacity of 46.9 m^3/s.

Concentration of nutrient, organic carbon and dissolved oxygen in the Nenskra River downstream of the power house has been estimated taking into account the following:

- Water quality of the turbined water – which is the same as the reservoir water quality and which evolves with time after reservoir filling, and
- Dilution of the turbined water by tributaries and the Enguri River.

The concentrations of nutrient, organic carbon and dissolved oxygen, over time taking into account dilution at different points downstream of the powerhouse are illustrated in Figure 28 and Figure 29.

A noticeable increase in the concentration of nutrients in the river water downstream of the powerhouse discharge in the first few years after reservoir filling can be expected. However, after in the order of 3 years after the reservoir filling, water quality will have improved – as most of the nutrient input from soils and vegetation will have been flushed out – and the nutrient levels in the water will be close to those of the natural conditions. There will probably be no noticeable change in the concentration of DO because of the dilution and the re-oxygenation of the turbined water.

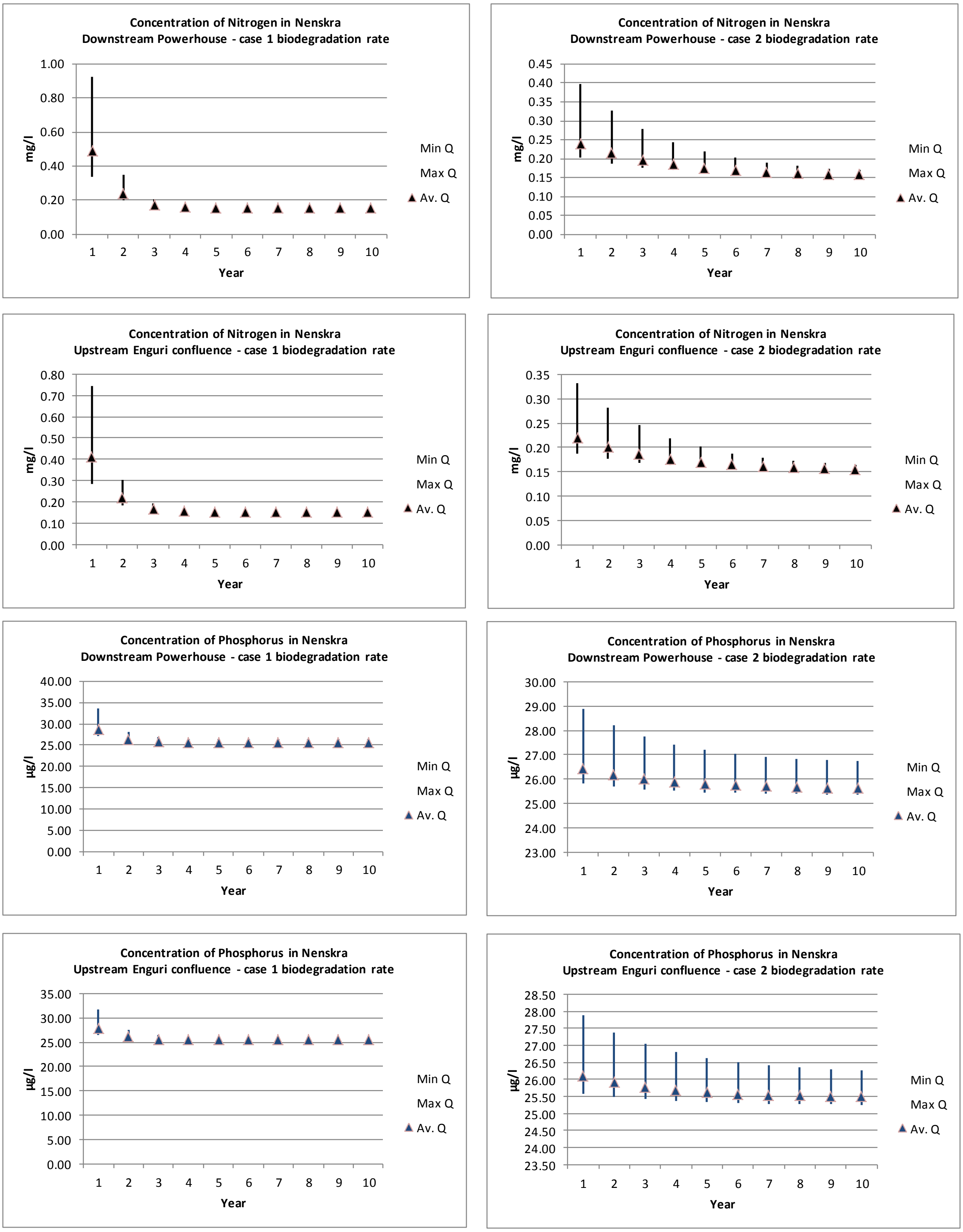


Figure 28 – Evolution over time of N and P in the Nenskra River downstream of the powerhouse

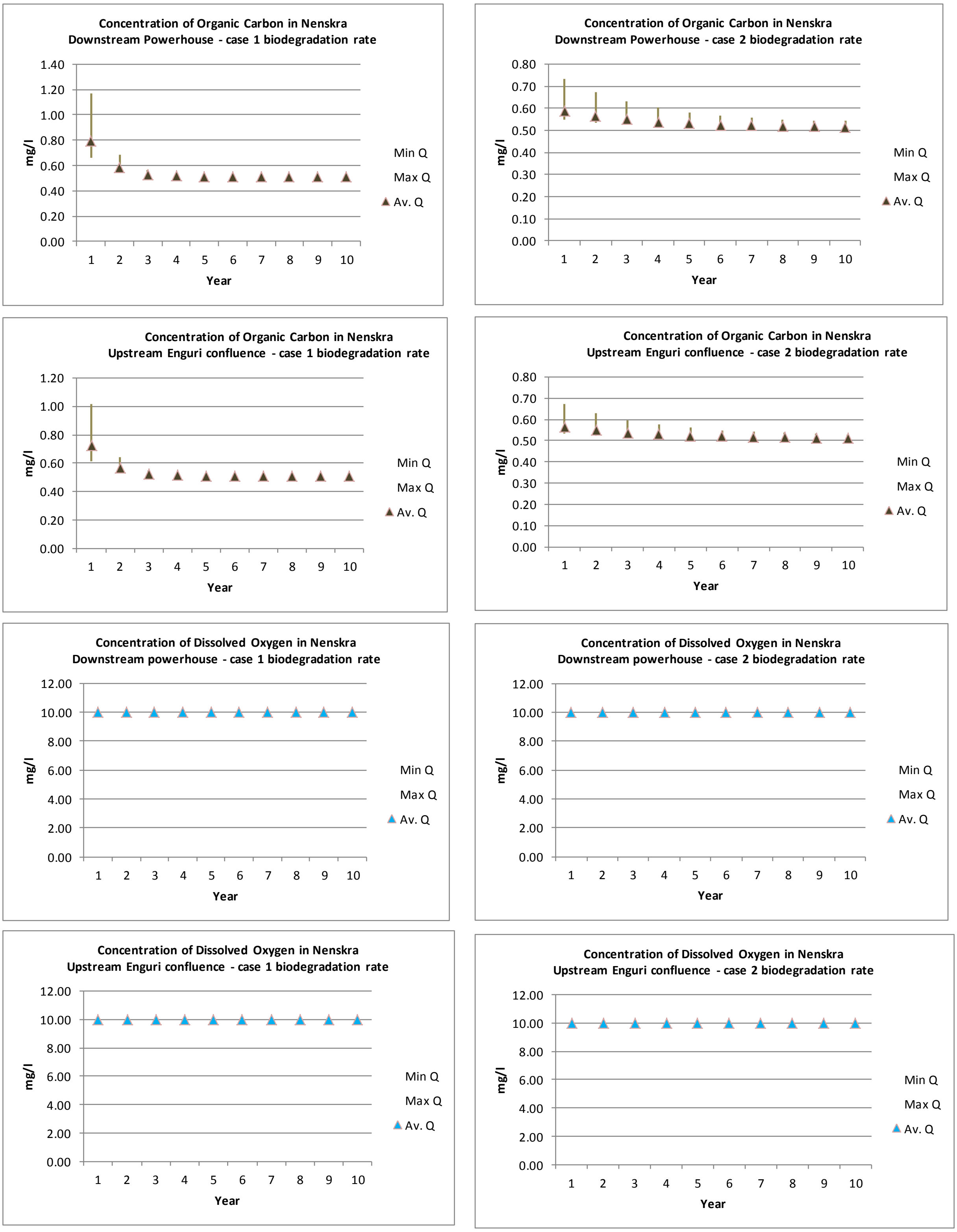


Figure 29 – Evolution over time of C and DO in the Nenskra River downstream of the powerhouse

7.5.2.2 Water quality changes in the case of spillage

It can be expected that 2 years out of 10 will be a wet year, and there is a possibility that there will be spillage of water via the spillway See §4.5. If the spillage occurs in the first years following reservoir filling the reservoir water will be of a modified nature with low DO and high nutrient content. The spillage is expected to be of a short duration in the order of 2 to 4 hours per day. Nevertheless the spillage is expected to cause a short term change in water quality downstream. The predicted concentrations of the nutrients and dissolved oxygen in the river water at various points between the dam and the powerhouse are presented in Figure 30 and Figure 31. The results show that the concentrations at the different points are very much the same for a given year.

Two cases of spillage are presented: (i) the case of spillage with the powerhouse turbines in operation. The spillage rate is estimated to be typically 20 m^3/s, and (ii) the case of spillage without the powerhouse turbines in operation, which corresponds to the sum of 20 m^3/s plus the rate normally discharged by the turbines – which is 46.9 m^3/s. The spillage rate is therefore in the order of 67 m^3/s.

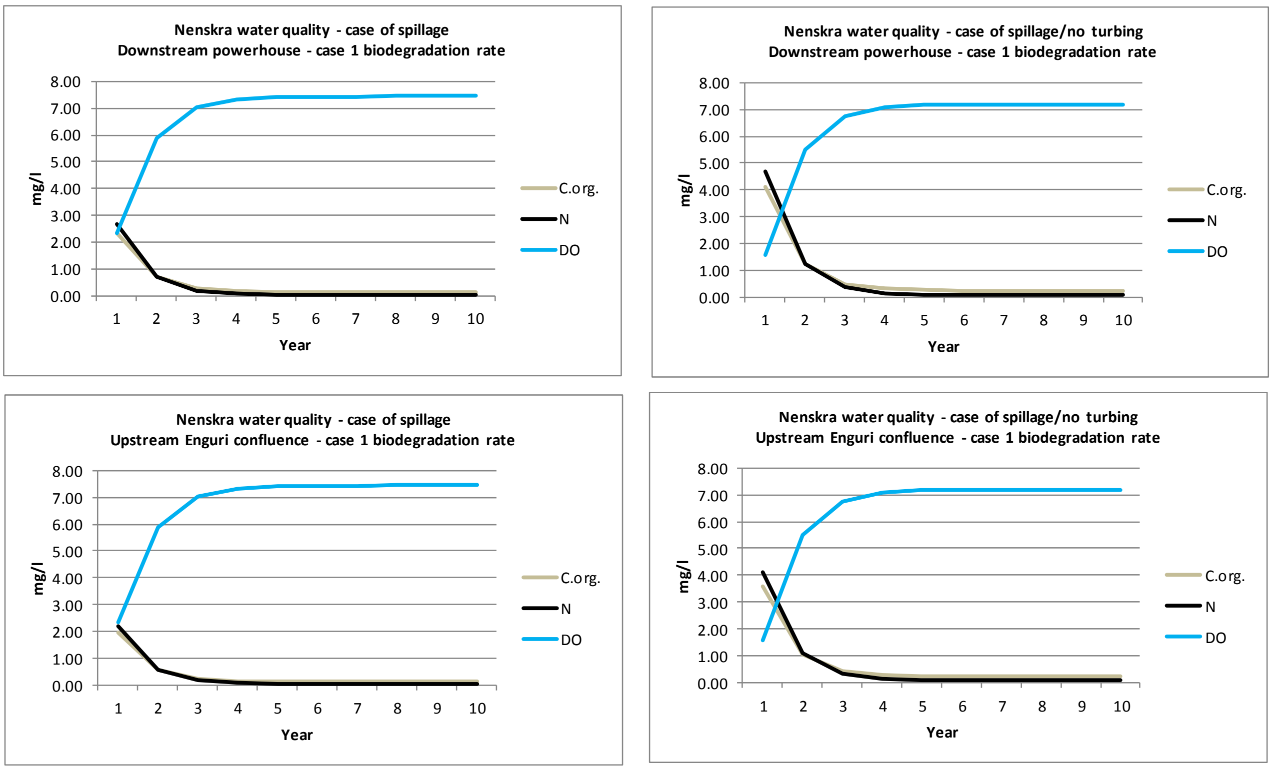


Figure 30 – Concentrations of nutrients and DO in the Nenskra River downstream of powerhouse in the event of spillage – biodegradation case 1

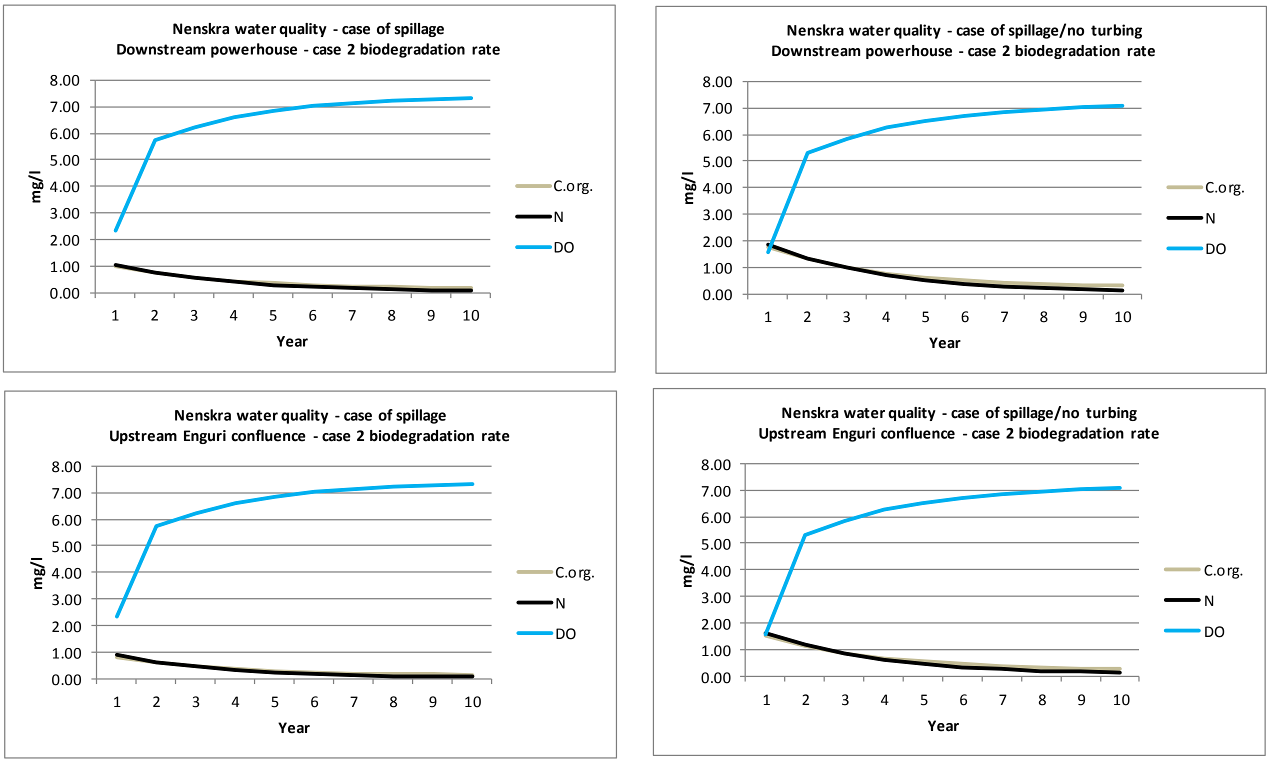


Figure 31 – Concentrations of nutrients and DO in the Nenskra River downstream of powerhouse in the event of spillage – biodegradation case 2

7.5.2.3 Water quality changes in the event of flood events

During the flood events of fairly high return periods such as between 5 and 25 year floods, the impact on water quality will be of the same order of magnitude as for the case of dam spillage described above. For more important flood events the presence of the dam and the quality of the reservoir water will not contribute significantly to effects on water quality during a flood event and in the event of flood events water quality will be much the same as for natural conditions.

7.5.3 Potential water quality impact on the Enguri reservoir

The key factors that could influence the importance of the impact of the modified Nenskra water inflow on the Khudoni reservoir water are as follows:

- The Nenskra inflow represents 25 percent of the total inflow to the Enguri reservoir, the other inflows are the Enguri River (69 percent) and the Tkheishi River (7 percent);
- The vegetation in the inundated area of the Enguri reservoir has mostly been modified since the reservoir filling in the 1970's.
- In terms of water throughput the Enguri reservoir has a storage volume of 1,110 million cubic metres, and a throughput of 4,100 million cubic metres. The throughput therefore represents 3.7 reservoir volumes per year.

Taking the above factors into consideration the potential impact of Nenskra modified water on the Enguri reservoir can be estimated. The inflow of nutrients and organic carbon with the modified Nenskra reservoir water into the Enguri reservoir will probably represent a discernible increase in the reservoir's nutrient and organic carbon input. However, this is offset by the dilution from the Enguri River and the volume of the reservoir – which is 6 times the volume of Nenskra. The concentrations of nutrients and organic carbon from Nenskra will be diluted by a factor of 7. Therefore nutrients and organic carbon in the Enguri reservoir are not expected to reach levels causing eutrophic conditions and the cumulative impact on Enguri reservoir water quality is not expected to be discernible from inter-annual variations.

7.6 Predicted water quality downstream of the Nakra water intake

Limited impact on water quality is expected downstream of the Nakra water intake. The intake comprises a diversion weir with a small inundated area upstream. The retention time in the inundated area will be very short and no impact related to increased levels of nutrients or organic carbon is expected.

However, the Nakra will be affected by reduced water flow as described in §4 and the reduced flow may have an effect on water temperature. The Nakra River baseline water temperature is expected to be very similar to that of the Nenskra baseline conditions which is presented in Table 34 below.

Table 34 – Nenskra River Water Temperature (°C) Lakhami (1980–1989)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Monthly mean	2.5	3.0	4.9	7.8	9.4	11.7	12.4	12.1	11.3	9.7	7.4	3.7	8.0
Monthly max.	4.4	5.4	8.6	10.9	12.1	15.0	14.3	14.3	12.8	11.2	10.6	7.6	10.6
Monthly min.	1.5	1.9	2.8	4.2	5.9	6.6	8.4	8.9	9.2	7.8	4.5	1.7	5.3

Source: Stucky, 2012a

The water temperature once the project has been implemented and the diversion weir constructed is expected to be influenced by air temperature, the origin of the water and origin and dilution from tributaries. The dilutions of the river at different locations downstream of the weir are presented in Section 5.1 and illustrated in Map 5-1 – Hydrological impacts.

During the cold winter months there is little glacial melt water and the river will be fed primarily with rainwater runoff. The flow rate during this season is not significantly different from the case without the weir and consequently, little if any change in water temperature is expected.

During the summer months, the Nakra River – for the case without the project – is fed primarily with glacial melt water. However, with the diversion in place flow rate will be significantly reduced. Nevertheless the flow from the tributaries also originates from glacial melt water and although the flow rate is reduced the temperature is expected to be similar to that of natural conditions without the Project.

7.7 Mitigation strategy and monitoring program

7.7.1 Mitigation strategy

7.7.1.1 Construction measures

A. Runoff management and silt traps to prevent fine solid material entering the river

Runoff management will comprise the adoption of the following measures:

- Construction worksites should be equipped with rainwater drainage systems with silt traps to prevent runoff with high silt or sediment load discharging into the Nenskra or Nakra Rivers;
- Runoff drainage channels should be created around worksites and any areas of dumped spoil to prevent runoff from entering the worksite/spoil dump area, the drainage channels should divert collected runoff to silt trap;
- The rock and gravel materials that are used for the construction of the dam structure could represent a source of fine materials that could be transported to the Nenskra River by rainfall and runoff. Silt traps or a cascade of silt traps should be installed downstream of the dam structure to collect any such silt. The silt traps are to be in place before any dam construction works start;
- Water draining from the transfer tunnel during construction is to be retained in a buffer basin before discharge to the Nenskra. The basin is to decant any silt or sediment and allow the quality of the water to be checked before discharge. This is to ensure the pH and presence of any heavy metals; and
- Areas cleared of vegetation for temporary facilities are to be revegetated at the end of the construction work. Spoil dumps are to be constructed to ensure stability and are to be revegetated to prevent erosion from runoff.

This set of measures is referred later in this report as:

- [WAT 25] Runoff and dewatering sediment control measures will be implemented using silt traps and runoff drainage channels.
- [WAT 26] Temporary areas cleared of vegetation will be revegetated.

B. Management of risk of acid rock drainage

Because it is possible that there may be sulphur bearing rocks within the rock tunnelled by the TBM, there is a possible risk of Acid Rock Drainage (ARD) from the spoils exposed to atmosphere and rain. Consequently, there needs to be plan for managing this risk, which should include as a minimum the following:

- Procedures and resources for checking for the potential presence of sulphur bearing rock in the spoils from tunnelling;
- Geochemical testing of the suspected sulphur bearing rock in tunnels to evaluate the risk of ARD and heavy metal leaching:
- Dedicated management of spoil that represents a risk of ARD:
    - Measures must be put in place to prevent water that has seeped through the spoils and which is acidic from being discharged into the environment without neutralisation and confirmation of the absence of heavy metals.
    - This could be in the form of catchment basin lined with impervious material, and neutralisation of the drained water using static mixer and pH adjustment.

These measures are referred later in this report as:

- [WAT 27] Preparation and implementation of an ARD and other geochemistry risk assessment programme for the tunnelling activities including definition of management of spoils representing an ARD risk or other geochemistry risks

C. Vegetation clearing and management of cleared biomass

Clearing of vegetation in the reservoir area is a contractual requirement from the EPC Contract. This commitment is referred later in this report as:

- [WAT 28] Reservoir vegetation clearing.

However, the following measures will be implemented regarding the vegetation clearing:

- Trunks of trees of economic value cut in the reservoir are to be set aside for monetization. The monetization will be managed by the forestry authorities in accordance with national legislation. This measure is referred later in this report as:
  - [WAT 29] Reservoir trees of commercial value transferred to local forestry authorities.

- Tree trunks and branches of trees cut in the reservoir that are not of economic value are not to be burnt. Solutions to make good use of this material are to be identified.
  - Possible uses could include the following: household firewood in other parts of Georgia, combustible material in cement works (a common user of waste combustible material), fuel for any municipal wood burning thermal power plants, export to overseas wood burning power plants. This measure is referred later in this report as:
  - [WAT 30] Marketing of non-commercial trees cut from reservoir

- Soft biomass, leaves and undergrowth are not to be burnt. Solutions for this vegetative material to be dispersed in a controlled manner and to be left to decompose naturally are to be investigated. The feasibility of “mulching” some of the soft biomass for future use in the revegetation of disturbed areas is to be evaluated. These measures are referred later in this report as:
  - [WAT 31] Biomass that is not of economic value is not to be burnt
  - [WAT 32] Solutions for soft biomass management will be identified

D. Pollution prevention and control

Potential sources of pollution include accidental spills and leaks of hazardous substances and discharge of sanitary and domestic wastewater.

Measures to prevent accidental spills and leaks include the following:

- Construction pollution prevention and control plan is to be developed and implemented;
- All tanks containing hazardous substances (such as diesel) are to be equipped with a secondary containment (bunding) which has a volume equal to 110 percent of the tank volume;
- Tanks are to be equipped with level detectors and safety systems to prevent overfilling;
- Secondary containment bunds are to be maintained empty of rainwater;
- Storage areas for hazardous substances are to be protected from adverse weather conditions, have impervious hard surfaces as a base and be equipped with secondary containment bunds to collect any spills or leaks;
- All handling or transferring of hazardous substances is to be performed on impervious surfaces equipped with spill retention;
- Equipment and materials for clean-up of accidental spills are to be available on site. Polluted soils are to be removed and managed as hazardous waste, and
- Runoff from worksite areas where hazardous materials are stored or handled is to be collected and routed to an oil-water separator for separation of hydrocarbons before discharge of runoff to the natural environment.

These measures are referred later in this report as:

- [WAT 33] Pollution prevention and protection plans and measures, including bunding of all inventories of hazardous materials, tank overfilling prevention measures.

Measures to prevent and control pollution from sanitary and domestic wastewater is essentially that the construction work camp is to be equipped with a wastewater treatment plant specified for discharges to comply with IFC EHS guidelines. This measure is referred later in this report as:

- [WAT 34] Construction work camp equipped with wastewater treatment plant with discharges compliant with IFC EHS guidelines.

7.7.1.2 Operational measures

A. Diversion of the small seasonal tributary on the right bank at the dam site

During the first years after reservoir filling, the only flow in the Nenskra River immediately downstream of the dam is the ecological flow from the reservoir. However, this flow could be modified with high nutrient content, high organic carbon content and low Dissolved Oxygen – and consequently degrade downstream ecology over a distance of about 2 to 3 kilometres.

In order to minimise this impact, is it suggested that:

- if monitoring of the ecological flow detects significantly eutrophic water (Phosphorus concentration >84.4 micrograms per litre or nitrogen concentration > 1.875 milligrams per litre) and causing significant impacts on aquatic ecology, then the ecological flow should be stopped. In this case the ecological flow should be replaced (for a short duration) by the seasonal stream that descends the mountain side on the right bank at the dam site, and is diverted by the Project into the reservoir. This measure is referred later in this report as:
    - [WAT 35] Small diversion weir design to allow by-pass

- The stream should be diverted back to its original course and allowed to flow into the Nenskra downstream of the dam and replace the ecological flow if monitoring of the ecological flow detects significantly modified water. This will not be possible all the year since the stream is dry in the winter period. This measure is referred later in this report as:
    - [WAT 36] Replace the ecological flow by the seasonal stream in case of modified water quality.

B. Planning of sediment venting

The reservoir is not expected to trap significant amounts of sediment. The bottom outlet inlet is situated at an altitude of 1,316 metres, which is about 16 metres above the bottom of the reservoir at the dam site. Consequently venting of sediment or accumulated organic material from the bottom of the reservoir by opening the bottom outlet gate will probably not be effective during the early years of operation.

However, in later years when more significant amounts of sediment have accumulated in the reservoir, there may be a need to vent sediment to prevent it from blocking the bottom outlet.

It is expected that the correct functioning of the bottom outlet gate will need to be verified at least once a year, and this will provide an opportunity to perform flush out sediment venting in later years as required. It is recommended that is programmed to be carried out during flood events in order to minimise any impacts on the downstream river quality. This measure is referred later in this report as:

- [WAT 37] Annual opening of bottom outlet is programmed during flood events

7.7.2 Monitoring program

The overarching objective of the monitoring programme will be to carry out a long-term, standardised measurement and observation of the aquatic environment in order to define status and trends.

The monitoring programme encompasses the Nenskra reservoir, the Nenskra River downstream of the dam-reservoir and the Nakra River downstream of the diversion weir. This measure is referred later in this report as:

- [WAT 38] Water quality monitoring program

Water quality monitoring during construction is carried out by the EPC Contractor and parameters and monitoring locations are documented in the Construction ESMP.

7.7.2.1 Parameters

Parameters to be monitored in reservoir water are listed in Table 35 below.

Table 35 – Water quality monitoring parameters for reservoir water

• Temperature	• pH
• Dissolved oxygen	• Total phosphorus
• Turbidity	• Phosphates
• Total suspended solids	• Ammonia
• Conductivity	• Nitrate
• Total alkalinity	• Nitrite
• Organic carbon	• Chlorophyll-a

Parameters to be monitored in river water are listed in Table 36 below.

Table 36 – Water quality monitoring parameters for river water

• Temperature	• Phosphates
• Dissolved oxygen	• Ammonia
• Turbidity	• Nitrate
• Total suspended solids	• Nitrite
• Specific conductance	• Total Petroleum Hydrocarbons
• Total alkalinity	• Benzene, Toluene, Ethylbenzene, Xylene (BTEX)
• pH	• EPA 13 Priority pollutant Metals (PP-13*)
• Total phosphorus	• Total coliforms
• Organic carbon	• Faecal coliforms

*** PP-13: (Sb) Antimony, (As) Arsenic, (Be) Beryllium, (Cd) Cadmium, (Cr) Chromium, (Cu) Copper, (Pb) Lead, (Ni) Nickel, (Se) Selenium, (Ag) Silver, (Tl) Thallium, (Zn) Zinc, and (Hg) Mercury**

7.7.2.2 Stations

The proposed monitoring stations are presented in Map 7.1. Monitoring frequency and parameters are described in Table 37 overleaf.

The rational regarding timing of monitoring during operation is explained as follows:

- Upper reaches of reservoir is monitored twice a year: in November when full and in May when this part of the reservoir begins to be flooded;

- Middle of reservoir and near dam is monitored twice a year: in November when full and in March when water is at its lowest level;
- Rivers are monitored twice a year: in July when flow rate is at its highest and in January when flow rate at its lowest.

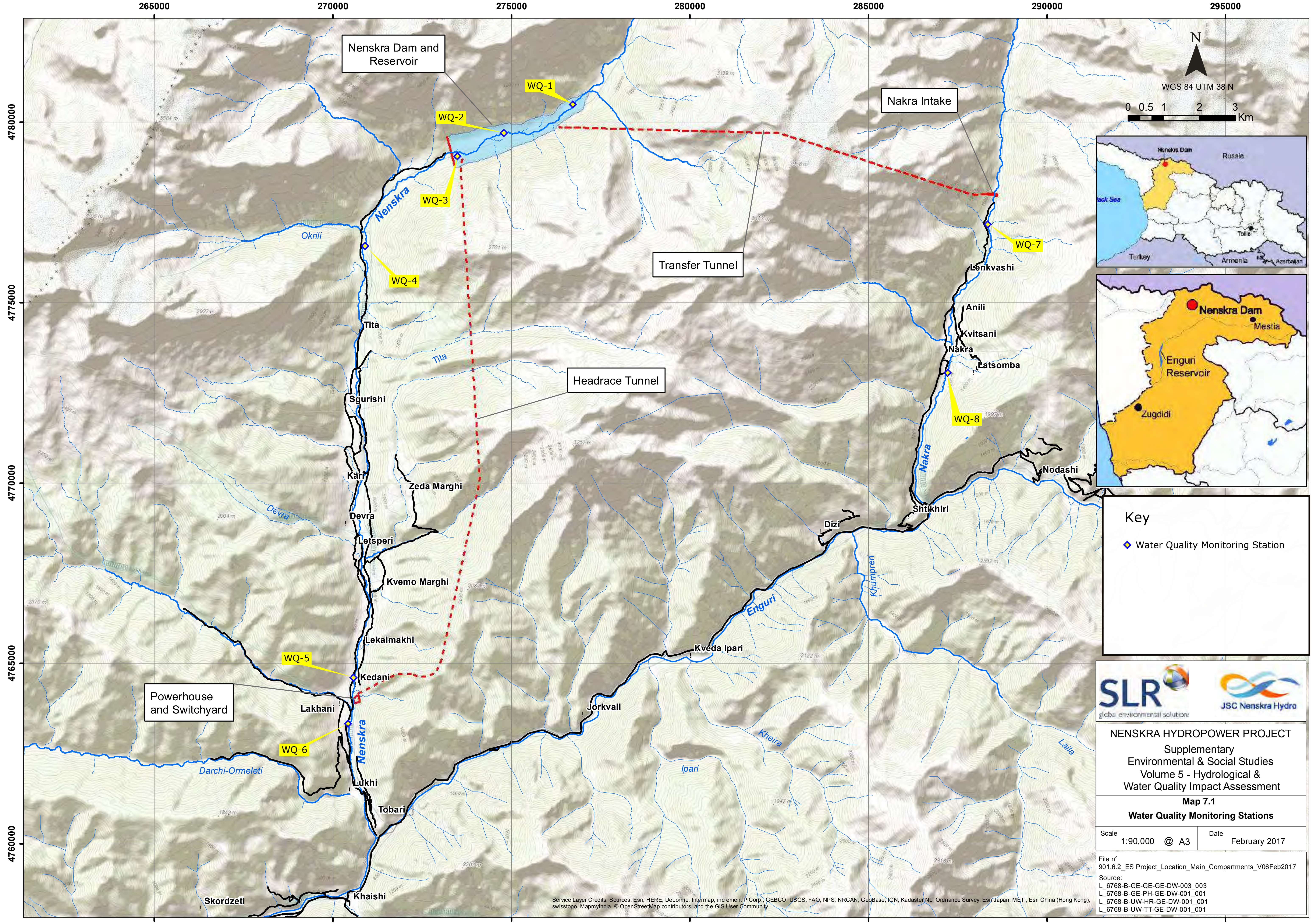
7.7.2.3 Reporting

Report is to be made monthly during construction, monthly during the first 5 years following reservoir filling and every quarter during operation.

Table 37 – Water quality monitoring stations and monitoring programme

Monitoring station	Location	Parameters measured	Monitoring frequency		Commentary
			Construction period	Operation	
WQ-1	Upper reaches of reservoir	Parameters listed in Table 35	Monthly	Monthly in the first 5 years following reservoir filling. May, and November in subsequent years	3 depths: surface mid-depth and bottom
WQ-2	Middle of reservoir	Parameters listed in Table 35	Monthly	Monthly in the first 5 years following reservoir filling. March, and November in subsequent years	3 depths: surface mid-depth and bottom
WQ-3	Reservoir proximity to dam	Parameters listed in Table 35	Monthly	Monthly in the first 5 years following reservoir filling. March, and November in subsequent years	3 depths: surface mid-depth and bottom
WQ-4	Nenskra River downstream of confluence with Okrili	Parameters listed in Table 36[a]	Monthly	Monthly in the first 5 years following reservoir filling. July, and January in subsequent years	N/A
WQ-5	Nenskra River upstream of powerhouse	Parameters listed in Table 36[a]	Monthly	Monthly in the first 5 years following reservoir filling. July, and January in subsequent years	N/A
WQ-6	Nenskra River downstream of powerhouse	Parameters listed in Table 36[a]	Monthly	Monthly in the first 5 years following reservoir filling. July, and January in subsequent years	N/A
WQ-7	Nakra River at downstream of diversion weir	Parameters listed in Table 36[a]	Monthly	Annual	N/A
WQ-8	Nakra River at Nakra village	Parameters listed in Table 36[a]	Monthly	Annual	N/A

[a] Monitoring of non-detected PP-13 Metals may be stopped at the end of construction period



Nenskra Dam and Reservoir
WQ-1
WQ-2
WQ-3
WQ-4
WQ-5
WQ-6
WQ-7
WQ-8
Nakra Intake
Transfer Tunnel
Headrace Tunnel
Powerhouse and Switchyard
Nenskra
Okrili
Tita
Devra
Darchi-Ormeleti
Enguri
Nakra
Khumpreri
Kheira
Ipari
Laila
Tita
Sgurishi
Kari
Zeda Marghi
Devra
Letsperi
Kvemo Marghi
Lekalmakhi
Kedani
Lakhani
Lukhi
Tobari
Khaishi
Skordzeti
Jorkvali
Kveda Ipari
Dizi
Shtikhiri
Nodashi
Lenkvashi
Anili
Kvitsani
Nakra
Latsomba
N
WGS 84 UTM 38 N
0 0.5 1 2 3 Km
Nenskra Dam
Russia
Black Sea
Turkey
Armenia
Azerbaijan
Tbilisi
Nenskra Dam
Mestia
Enguri Reservoir
Zugdidi
Key
Water Quality Monitoring Station
SLR global environmental solutions
JSC Nenskra Hydro
NENSKRA HYDROPOWER PROJECT
Supplementary Environmental & Social Studies
Volume 5 - Hydrological & Water Quality Impact Assessment
Map 7.1
Water Quality Monitoring Stations
Scale 1:90,000 @ A3
Date February 2017
File n° 901.6.2_ES Project_Location_Main_Compartments_V06Feb2017
Source:
L_6768-B-GE-GE-GE-DW-003_003
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Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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8 Climate change

8.1 Observed and predicted effects of climate change

Modelled climate change impacts on temperature and precipitation for several regions in Georgia were evaluated by the UNDP (UNDP, 2015) and conclusions made on the trends. The Upper Svaneti region has been particularly studied (UNDP, 2014) as part of the preparation of Georgia's Third Communication on Climate Change to the UNFCCC in 2015. The evaluation was performed in two phases: (i) Current climate change evaluation based on existing static data; and (ii) Long term forecast of social-economic changes considering various scenarios.

Trends in the average annual air temperature and precipitation have been studied for the periods 1961 to 1985 and 1986 to 2010. The future changes for these two parameters have been estimated for two periods 2021-20150 and 2071-2100. The future climate change scenario was evaluated using the regional RegCM4 model, in which the global ECHAM5 model and the world's socio-economic development A1B scenario were used.

Trends from 1961 to 2100 given in Table 38 for Khaishi and Mestia; their meteorological stations are the closest from the Nenskra and the Nakra valleys. The Mestia Meteorological Station is located at elevation 1,441 metres asl. The Khaishi Meteorological Station is located at elevation 730 metres asl.

Table 38 – Observed and predicted effects of climate change – Mestia and Khaishi

Parameter	Mestia	Khaishi
Mean annual T°C		
T1: 1961-1985	5.8 °C	10.5°C
T2: 1986 – 2010	6.1°C	10.9°C
T3: 2021-2050	7.3°C	12.0°C
T4: 2071-2100	9.8°C	14.5°C
Variations T1 / T2	+0.3°C	+0.4°C
Variations T2/T3	+1.2°C	+1.1°C
Variations T2/T4	+3.7°C	+3.6°C
Annual Precipitation		
P1: 1961-1985	961.8 mm	1,213.9 mm
P2: 1986 – 2010	1,058.4 mm	1,399.2 mm
Variations P1/P2	+10%	+15%
P3: 2021-2050	1,075 mm	1,336 mm
P4: 2071-2100	991 mm	1,174 mm
Variations P2/P3	+2%	-5%
Variations P2/P4	-6%	-16%

Sources – UNDP 2015, Georgia's Third National Communication to the UNFCCC

8.1.1 Observed regional changes

In Mestia, during the period 1986-2010 precipitation has increased by 10 percent and mean annual air temperature has increased by 0.3 degrees Celsius. In Khaishi, during the same period, precipitation has increased by 15 percent and mean annual air temperature has increased by 0.4 degrees Celsius. The seasonal variations are summarized in the table below.

Table 39 – Observed effects of climate change in Mestia and Khaishi in 1986-2010

Station	Winter	Spring	Summer	Autumn
Mestia	Insignificant chilling (-0.1°C). Precipitation increased by 30%.	Insignificant warming (+0.1°C). Precipitation increased by 18%.	Warming by 0.7°C. Precipitation decreased by 8%. Recurrence of abundant precipitation (≥50 mm) halved during 1986-2010	Warming by 0.5°C. Precipitation increased by 10%.
Khaishi	No change in temperature Precipitations increased by 12%. 2 days with extreme precipitation (≥90 mm) in 1986-2010 not observed in 1961-1985.	Insignificant warming (+0.1°C). Precipitation increased by 21%.	Warming by 0.4°C. Precipitation increased insignificantly.	Warming by 0.8 °C Precipitation increased by 14%.

Sources – UNDP 2014, Upper Svaneti Adaptation Strategy to the Climate Change

During the last 50 years, climate change in Mestia and Khaishi led to increase in temperature mostly during autumn in Khaishi (+0.8 degrees Celsius) and mainly during summer in Mestia (+0.7 degrees Celsius). The seasonal temperatures on both meteorological stations remained virtually unchanged in winter and spring. The frequency of disastrous events caused by heavy precipitation has also increased and is reflected in increased losses causes by floods and landslides.

8.1.2 Predicted regional changes

The climate change for 2100 is forecast to comprise the following:

- An incremental increase of annual temperature that could reach 3.7 degrees Celsius;
- Decrease in annual precipitation of 67 millimetres (Mestia) and 225 millimetres (Khaishi) compared to the 1986, corresponding to a 6 and 16 percent decrease respectively.

The predicted seasonal variations between 1986-2010 and 2070-2100 are summarized in the table below.

Table 40 – Predicted effects of climate change in Mestia and Khaishi in 2100

Station	Winter	Spring	Summer	Autumn
Mestia	Warming by 3.7°C. Precipitation decreased by 11%.	Warming by 3.1°C. Precipitation decreased by 9.6%.	Warming by 4.1°C. Precipitation increased by 16.1%.	Warming by 4.1°C. Precipitation decreased by 20.7%.
Khaishi	Warming by 3.5°C. Precipitation decreased by 2%.	Warming by 2.9°C. Precipitation decreased by 17.4%.	Warming by 4.4°C. Precipitation decreased by 14.2%.	Warming by 3.8°C. Precipitation decreased by 21.7%.

Sources – UNDP 2015, Georgia's Third National Communication to the UNFCCC

The climate change scenario predicts decrease of precipitation in winter, spring and autumn respectively. Precipitation will increase by 16 percent in summer in Mestia and will decrease by 14 percent in winter.

Georgia's Third National Communication reports that during the period between 1890-1965 the area occupied by glaciers in the Upper Svaneti was reduced by 13 percent and in the same period the average annual temperature increased by 0.3 degrees Celsius. A linear extrapolation of current trends predicts that by the year 2100 the Upper Svaneti air temperature will increase by a further 4 degrees Celsius and the area covered by glaciers will have been reduced to cover 100 square kilometres.

8.1.3 Changes in the catchment area as a result of climate change

The general trends in the catchment area that could be expected as a result of climate changes are outlined as follows:

- The increase in temperature is expected to result in the continuation and acceleration of the progressive reduction in the areas covered by glaciers;
- The reduced precipitation in the summer months may not have a discernible effect on hydrology. This is because the principle source of run-off in summer is from glacial melt water. However, run-off could increase because of increased melting of glaciers;
- In the winter months the decrease in precipitation will probably not have a discernible effect on hydrology as precipitation in the winter is mostly in the form of snow. However, the rise in temperature may increase run-off because a larger proportion of precipitation will be in the form of rain (rather than snow).
- The increased run-off linked to the increase in the amount of precipitation falling as rain and increased melting of glaciers could result in increased sediment transport.
- Climate change also increases the frequency and intensity of extreme events – such as periods of intense heat, storms, periods of sudden cold weather and periods with unusually high precipitation. These types of events could result in increased frequency of debris flow or mid flow events in the catchment area and result in increased sediment inflow into the reservoir and increase transport of floating debris such as dead trees, logs, vegetation.
- The reduced precipitation in winter but with an increase in freak weather conditions may modify the snow accumulation and avalanche regime.
- In the long-term the climate change may result in a change in vegetation cover, which may also cause increased surface erosion.

The Project will monitor all the above aspects; the project will install weather stations, a gauging station to monitor reservoir inflow, snow accumulation will be monitored and sediment accumulation in the reservoir will be monitored. Monitoring results will be maintained in a project database to identify any trends that might need to be managed through adjustments to the operational regime.

The only potential risk identified for the project requiring to be accounted for in the design of the dam and resulting from climate change is that of a possible increase in extreme rainfall and flooding events as could potentially influence the PMF value. Consequently, JSCNH will undertake a dedicated climate change risk assessment in alignment with best international practices to model and verify the PMF value that the spillway will be designed to evacuate safely. Two commitments have been identified and are referred to later in this report as:

- [WAT 39] Climate change risk assessment
- [WAT 40] Design criteria for flood control in alignment with findings of the Climate Change Risk Assessment.

8.2 Greenhouse gas assessment

8.2.1 Assessment methodology

The Greenhouse Gas (GHG) Assessment comprises estimating the GHG emissions from dam construction activities and emissions from the reservoir as a result of the flooding of the inundated area.

8.2.1.1 Assessment methodology for construction GHG emissions

Construction GHG emissions comprise essentially diesel combustion emissions (mainly carbon dioxide) from the diverse earth moving and construction vehicles used to construct the dam.

The method for the estimation of emissions is that published by the French Agency for the Environment and Energy – *Agence de l'Environnement et de la Maitrise de l'Energie* (ADEME, 2007) and which is in alignment with the EBRD GHG Assessment Methodology.

The emissions are calculated using the EPC contractor's estimations of the amount of the different types of construction material required and multiplying these quantities by ADEME emission factors. The product of the quantities multiplied by the emission factor is the corresponding GHG emission.

8.2.1.2 Assessment methodology for reservoir GHG emissions

Reservoir GHG emissions comprise the carbon dioxide released as a result of the biodegradation of the flooded biomass. The method used for estimating the emissions comprises the following steps:

- Determination of the area to be flooded;
- Estimation of the quantities of biomass in the flooded area (see section 7.3 and 7.4.2.3). Hard biomass present in trees is not taken into account in the calculation as it is assumed that the trees will be cleared prior to reservoir filling.
- Estimation of the quantity of carbon in the flooded biomass;
- Estimation of the biodegradation rate for biomass and for the release of labile carbon in soils – this provides the rate at which carbon is converted to carbon dioxide and hence GHG emissions;
- Estimation of the amounts of carbon dioxide produced on an annual basis as a result of biodegradation.
- It is assumed that cleared vegetation will not be burnt, and the measures to manage the burning of vegetation are described in section 7.7.1.1C.

The effect of Land-Use Change and Forestry (LUCF) on reservoir GHG emissions is negligible because of the small area occupied by the dam and the reservoir, which totals only 400 hectares.

8.2.2 Input data and assumptions

8.2.2.1 Input data and assumptions for construction emissions

The input data for construction GHG emissions are presented in Table 41. The quantities of construction materials in cubic metres are from the schedule of quantities established by the EPC Contractor as part of their technical bid. The quantities in tonnes have been calculated using estimated densities.

Table 41 – Estimated quantities of construction materials

Construction Material	Quantity of material (m^3)	Density of material (kg/m^3)	Quantity of material (tonnes)	Emission factor Kg C_{eq}/t material [*]
clearing and grubbing	397,819	2,000	795,638	3
embankment for cofferdam	389,940	2,000	779,880	3
Rip-rap slope protection	8,500	2,000	17,000	3
Cofferdam removal	62,863	2,000	125,726	3
Cofferdam material	465,381	2,000	930,762	3
Open excavation	4,708,156	2,000	9,416,312	3
Dam embankment	14,539,613	2,000	29,079,226	3
Underground excavation (D&B)	189,921	2,000	379,842	30
Underground excavation (TBM)	567,823	2,000	1,135,646	30
Underground shaft	6,123	2,000	12,246	30
Underground enlargement	38,378	2,000	76,756	30
Shotcrete underground excavation	161,624	2,400	387,898	235
Underground reinforced concrete	201,852	2,400	484,445	235
Underground concrete lining	216,193	2,400	518,863	235
Backfill concrete	18,895	2,400	45,348	235
Reinforced structural concrete	71,656	2,400	171,974	235
Steel reinforcement	11,007	8,050	88,606	870
Lean concrete	3,429	2,400	8,230	235
Formworks (concrete)	78,633	2,400	188,719	235

[*] Includes emissions from transport

8.2.2.2 Input data and assumptions for reservoir emissions

The methodology for estimating emissions is described in section 8.2.1.2 and the method for the estimation of the biomass in the reservoir area is presented in section 7.4.2.3. The biomass and carbon in the inundated area – assuming vegetation clearing – are summarised in Table 42.

Table 42 – Biomass and carbon in the inundated area – and decay rates

Type of biomass	Biomass (tonnes)	Carbon content	Carbon (tonnes)	Degradation rate (half-life)
Soft biomass (understory)	1,676	0.5 t / t biomass	838	1 year
Soils	101,790	85 g/kg	8,550	6 months

For the estimation of the reservoir GHG emission its assumed that the carbon in the biomass biodegrades producing carbon dioxide gas in an aerobic reaction, following an expedential decay rate with half-life of 20 years for hard biomass, 1 year for soft biomass and 6 months for labile carbon in soils. It is assumed that there is no methane produced from anaerobic biodegradation because of the high reservoir recharge rate and high DO concentration (see section 7.1. These assumptions are considered conservative (i.e. higher rate than is probably the case) and reflect decay rates reported in literature (Fearnside, 1995).

It is assumed that 100 percent of the hard biomass from tree trucks is recovered for economic use, used as firewood or in some way monetized. It is assumed that the soft biomass is not burnt but disposed of in a suitable manner and that the carbon is not released to atmosphere as carbon dioxide.

8.2.3 Assessment

A. Construction GHG emissions

GHG emissions from construction are presented in Table 43. The emissions will be generated over the 4 year construction period and represent 622,000 tonnes per year.

Table 43 – Estimated CO2-eq emissions during the 4 year construction period

Construction material	Quantity (tonnes)	Emission factor Kg C_{eq}/t material	C eq emissions (tonnes)	CO2-eq (tonnes) [*]
clearing and grubbing	795,638	3	2,387	8,752
embankment for cofferdam	779,880	3	2,340	8,579
Rip-rap slope protection	17,000	3	51	187
Cofferdam removal	125,726	3	377	1,328
Cofferdam material	930,762	3	2,792	10,238
Open excavation	9,416,312	3	28,249	103,579
Dam embankment	29,079,226	3	87,238	319,871
Underground excavation (D&B)	379,842	30	11,395	41,783
Underground excavation (TBM)	1,135,646	30	34,069	124,921
Underground shaft	12,246	30	367	1,347
Underground enlargement	76,756	30	2,303	8,443
Shotcrete underground excavation	387,898	235	91,156	334,238
Underground reinforced concrete	484,445	235	113,845	417,430
Underground concrete lining	518,863	235	121,933	447,087
Backfill concrete	45,348	235	10,657	39,075
Reinforced structural concrete	171,974	235	40,414	148,185
Steel reinforcement	88,606	870	20,822	76,349
Lean concrete	8,230	235	7,160	26,252
Formworks (concrete)	188,719	235	44,349	162,613
TOTAL			**621,904**	**2,280,313**

[*] Includes emissions from transport. The EPC Contactors estimate of 14,800 vehicle trips between the powerhouse and the dam site, equivalent to 251,600 kilometres represents 350 tonnes CO2-eq over 4 years. Calculated using the ADEME emission factor of 372 g Eq. carbon per kilometre.

B. Reservoir emissions

The reservoir emissions are presented in Figure 32 and compared with worldwide benchmark values in Figure 33.

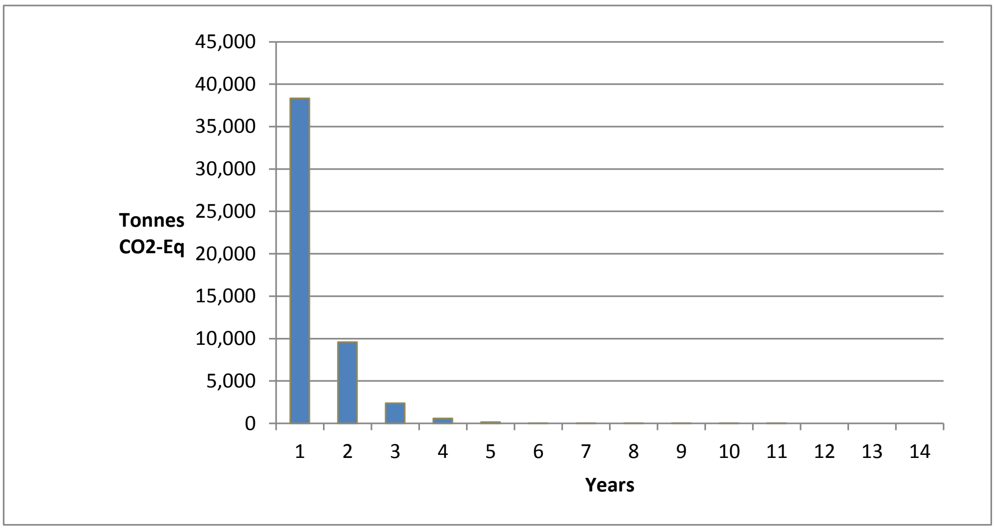
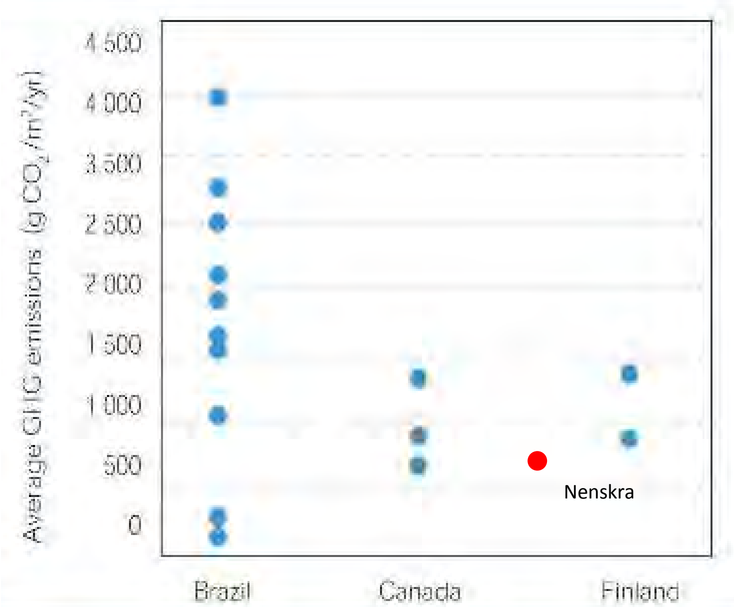


Figure 32 – Reservoir and Construction GHG emissions – with vegetation clearing



Note. The Nenskra emissions presented are averaged over 30 years and the averages presented for other regions mask strong seasonal and annual variations

Figure 33 – Comparison of reservoir emissions with worldwide benchmark values

Source: World Commission on Dams (WCD) report, 2000

C. Overall emissions

The total reservoir GHG[5] emissions covering the 4-year construction period and a 30-year period represents 2.33 million tonnes of equivalent carbon dioxide, which represents and average of 0.07 million tonnes of equivalent carbon dioxide per year, which translates as 32 grams CO_2eq/kWh. This compares favourably with typical values for reservoir hydropower projects which are reported to be in the range of 4 to 160 grams CO_2eq/kWh, with the majority between 4 and 38 grams CO_2eq/kWh (Intergovernmental Panel on Climate Change – IPCC, 2011).

8.2.4 Comparison of GHG emissions with alternative technologies

GHG for alternative technologies (oil, gas and coal) have been estimated using the method described in the *Greenhouse Gas Assessment handbook* (World Bank, 1998). The method comprises estimating the fuel consumption of oil, gas and coal based on energy requirements and the energy efficiency of the different fuels and the carbon content of the fuel per unit of energy. The calculation is presented in Table 44. Cumulative emissions over a period of 30 years for thermal power plant firing oil, gas, coal are compared with the emissions from the hydropower scheme. The dam construction emissions (2.4 million tonnes of CO2-eq) are taken into account in this comparison.

Table 44 – Estimation of GHG emissions from alternative technologies

Parameter used in the calculation	Oil	Gas	Coal	Units
Input				
Plant power capacity	280	280	280	MW
Annual electricity production	2.45×10^9	2.45×10^9	2.45×10^9	kWh
Calculated Fuel Requirements				
Conversion factor	3.6×10^6	3.6×10^6	3.6×10^6	J/kWh
Conversion efficiency [*]	0.35	0.4	0.33	None
Conversion factor	1.0×10^{12}	1.0×10^{12}	1.0×10^{12}	TJ
Fuel requirement	2.52×10^4	2.21×10^4	2.68×10^4	TJ/yr
Calculation of GHG emissions				
Average carbon content	20	15.3	27.6	tC/TJ
Carbon emission	5.05×10^5	3.38×10^5	7.39×10^5	tC/yr
Emission factor	3.667	3.667	3.667	None
Equivalent carbon dioxide emission per year	1.85	1.24	2.71	MtCO2-eq/yr

[*] Modern state-of-the-art thermal power plants may have slightly higher efficiencies than those indicated. However, efficiencies used in the calculations are representative values for a wide range of equipment types. Consequently, the estimated emissions indicate orders of magnitude and are indicative of the relative performance of the different technologies in terms of emissions with or without the use of state-of-the-art equipment.

[5] In addition to reservoir emissions, the schemes operation includes emissions from the Nakra weir 30 kVA power generator which emits 60 tonnes of CO_2eq per year. However, this represents <0.1% of overall emissions.

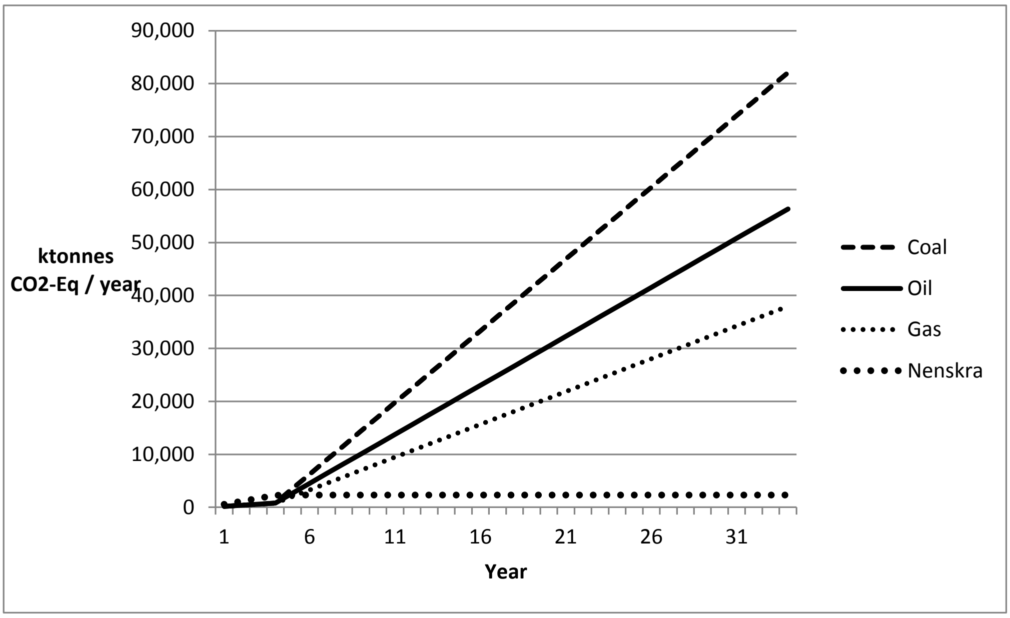


Figure 34 – Comparison of Nenskra HPP cumulative GHG emissions with alternative technologies

8.2.5 Comparison with Georgian and worldwide emissions

The Nenskra GHG emissions compared with national and worldwide emissions are presented in Table 45.

Table 45 – Nenskra HPP GHG emissions compared to national and worldwide GHG emissions

GHG Emissions	Emissions (tonnes) per year (average – including dam construction)	Percentage Project Emission
Nenskra Project emissions [a], [d]	0.07 million	---
National GHG emissions – without LUCF [a]	14.24 million	0.56%
Nett GHG National emissions – with LUCF [b]	10.78 million	0.74%
Worldwide GHG Emissions [c]	52,000 million	0.00015%

LUCF: Land-Use Change and Forestry

[a] Average over 30 years and including construction emissions. Vast majority of emissions are from construction during the 4 year construction period – see Figure 32.

[b] World Resources Institute (WRI) with data from 2012[6]

[c] IPCC Fifth Assessment Report, 2015

[d] Contribution of LUCP is considered as negligible because of the small size of the dam-reservoir (400 ha)

8.2.6 GHG offsets resulting from project implementation

The national GHG emission intensity (tCO2-eq per MWh) has been calculated for the situation when the Project has been implemented. The key figures are presented Table 46 below and it can be seen that the project is expected to result in a 9 percent reduction in the national emission intensity for electricity production.

[6] http://cait.wri.org/profile/Georgia

Table 46 – GHG offsite from Project implementation

Source	MWh per year	GHG emissions (million tonnes CO2-eq / year)	tCO2-eq / MWh
National electricity production [a]	9.476×10^6	3.155	0.330 [b]
Nenskra Project	1.19×10^6	0.07	0.059
National electricity + Nenskra	1.067×10^7	3.225	0.302
Reduction			9.2%

[a] US Energy Information Administration[7] [b] EBRD

8.3 Micro-climate changes

8.3.1 Introduction

Environmental impacts of some large dam-reservoirs include changes to the micro-climate. These changes are related to the creation of a large body of water. The water body, which has a higher heat capacity than the natural situation without a dam can – for large reservoirs – alter the air temperature in the vicinity of the reservoir. During hot period the mass of water will absorb heat and water will evaporate – thus lowering ambient air temperatures nearby and increasing humidity. During cooler periods the water in the reservoir will release heat at a slower rate than that of the natural environment without the dam – thus slightly increasing air temperatures in the vicinity. The scale of such changes to the micro-climate is dependent on a number of factors which are discussed in the following sub-section.

8.3.2 Assessment

The assessment of micro-climate changes that could occur as a result of the Nenskra reservoir impoundment in broken down onto a discussion regarding factors which are known to influence the scale and importance of micro-climate impacts. The analysis is consequently based on conjecture rather than a robust analysis and this is considered adequate as the Nenskra reservoir is relatively small in size.

8.3.2.1 Factors influencing scale and importance of micro-climate impacts

A. Size of the reservoir

The reservoir covers a relatively small size considering the power capacity of the scheme. This is because of the important altitude difference between the reservoir and the powerhouse. The reservoir area at maximum operating level covers 270 hectares – and the reservoir occupies this footprint for 3 month of the year. At minimum operating level the reservoir footprint is less than 100 hectares.

B. Prevailing climatic condition

The Nenskra reservoir, located in the Western Caucasus Mountains at an altitude of 1,300 metres is exposed to climatic conditions which are characterised by predominantly sub-zero temperatures during the period December – February and average temperatures in the range of 16 to 20 degrees Celsius during the warmest months of June to August.

[7] http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=2&aid=12&cid=r4,&syid=2007&eyid=2012&unit=BKWH

C. Reservoir operation

The reservoir is at its maximum operating level at the end of July and is maintained at this level until the end of November during this. From December to end of February / mid-March the reservoir water level is progressively lowered to the minimum operating level. From end of March to July the reservoir is progressively filled and the main inflow is glacial melt water.

D. Evaporation from the reservoir

The evaporation from the reservoir has been calculated by the Owners Engineer (Stucky, 2015) and represents 50 millimetres of reservoir water per month (average of 0.04 m^3/s). In terms of water input into the catchment basin as a whole, the evaporation rate can be compared to rainfall in the catchment basin – which covers 222 square kilometres at the dam site – and is 1,000 millimetres per year. The evaporation from the reservoir therefore represents 0.5 percent of rainwater input in the Nenskra valley.

E. Morphology of local terrain

The Nenskra reservoir will be located in a steep sided valley – at an altitude of 1,300 metres. The surrounding mountains reach altitude in the order of 3,000 metres. Downstream of the reservoir is a continuation of the valley occupied by the reservoir and which descends with a regular gradient to the confluence with Enguri River 21 kilometres from the reservoir and at an altitude of 700 metres.

F. Climate change

Climate change in the Caucasus Mountains as reported in Georgia's second national communication to the UNFCCC (2009). The report forecasts that the Kvemo Svaneti region could be subject to increments of annual temperature that could reach 3.5 degrees Celsius, accompanied by a decrease of precipitation of 60 millimetres.

8.3.2.2 Predicted changes to micro-climate

Taking into account the factors described above, the impacts on micro-climate that could result from the impounding of the Nenskra reservoir are expected to affect the immediate areas around the reservoir and could possibly be detected at Tita but probably no further down the valley. The possible effects could be slightly increased humidity and slightly lower temperatures in the summer months and slightly warmer temperatures in the autumn months.

However, it is probable that any changes to the micro-climate will be negligible compared to the effects of climate change on a regional scale. To demonstrate and monitor this prediction, the Project will install two weather stations at the dam site and the powerhouse. This measure is referred to later in this report as:

- [WAT 41] Project design includes microclimate monitoring stations in Dam site and in Chuberi.

9 Synthesis of impacts, significance and commitments

Table 47 next pages summarise all impacts, as well as the mitigation, compensation, safety and improvement measures (JSCNH commitments) identified as part of the Hydrology and Water Quality Impact assessment. The summary table refer to the measures marked [WAT] throughout this report. The [WAT] measures are not necessarily listed in the sequential order of their number.

Some of the measures are also proposed in other Supplementary E&S studies. They are all translated into implementable terms (management action, schedules, responsibilities) in Volume 8 "Environmental and Social Management Plan" of the Supplementary Environmental and Social Studies issued in 2016. For the sake of tracking and consistency, the summary table next page identifies which management plan of the ESMP addresses the commitment made in the present report.

Table 47 – Summary of impacts and commitments

Environmental or Social Value	Impact Producing Factor	Phase: Early Works	Phase: Main construction	Phase: Reservoir Filling	Phase: Operation	Assessment of significance without mitigation or compensation High Hi - Moderate M - Low Lo [+] positive, [-] negative Likelihood, Magnitude, Extent, Duration	Commitments: Key Mitigation, Compensation or Management measures	Predicted residual impact	Management Action where the mitigation or compensation measure is addressed in the ESMP
Surface water hydrology	Reduction of river flow between Nenskra dam and powerhouse due to Nenskra River diversion.	□	□	■	■	Hi [-] Certain. Significantly reduced flow rates in Nenskra River between dam and powerhouse: 5-15% of baseline over first 2 km down to Okrili River and 25%-40% of baseline over next 13km from Okrili River down to Powerhouse.	• [WAT 1] Mandatory Ecological flow downstream of Nenskra dam of 0.85 m3/s • [WAT 5] Availability and safety and ecological flow functions of the bottom outlet are ensured through careful siting, design, operational procedures and inspection, control & maintenance programmes. • [WAT 21] Hydrological monitoring and real-time monitoring and disclosure on a website of the ecological flow.	M [-]	Environmental & Social Management System: ESMS.2 Environmental Monitoring: MON2.
						Lo [+] Probable. Attenuation of small frequent flood events that occur outside the period when the reservoir is at maximum operating level. i.e. occur during the period November – June.	None	Lo [+]	N/A
						Hi [-] Probable. Spillage during month of August, 2 years out of 10 - with spillage rates in the order of 15 – 20 m3/s every day for a few hours causing an important and sudden variation in river flow downstream, ranging from 5 – 25 m3/s near the dam, to 20 – 40 m3/s near Chuberi	• [WAT 14] Access restrictions and warning systems downstream of dam site • [WAT 16] Public awareness campaigns	M [-]	Emergency Action Plan: EAP 2. – EAP.3
	Reduction of river flow downstream of Nakra water intake due to Nakra transfer.	□	□	□	■	Hi [-] Certain. Significantly reduced flow rates in Nakra River downstream of intake. In average: 15-25% of baseline down to Lekverari confluence (EF: 1.2 m^3/s), 25% to 40% of baseline from Lekverari confluence to Enguri River.	• [WAT 2] Mandatory Ecological flow downstream of Nakra weir of 1.20 m3/s. • [WAT 8] Ensure that sediment trapped upstream of the Nakra Intake is flushed downstream and that the ecological continuity of the river is maintained at all times during construction and operation with real-time monitoring and disclosure of the ecological flow on a website. • [WAT 21] Hydrological monitoring and real-time monitoring and disclosure on a website of the ecological flow. • See commitments in "Riverbed erosion & geomorphological changes" below for management of effects due to reduced bedload capacity.	M [-]	Environmental & Social Management System: ESMS.2 Environmental Monitoring: MON.2
						M [+] Probable. Reduced in small frequent flood events as diversion with capture up to $45m^3/s$	None	M [+]	N/A
	Increased river flow downstream of powerhouse due to reservoir storage and Nakra transfer.	□	□	□	■	Lo [-] Certain. Increased flow rates in Nenskra River from powerhouse to Enguri River. Average monthly increases range from 5% in June – which is the month with the highest flow rate – to 300% in winter, when there is low flow conditions for natural conditions.	• [WAT 4] Transfer of water from the Nakra River will be suspended to the extent possible in order to avoid spillage at the Nenskra dam. • [WAT 18] Flood studies include the reach downstream from the powerhouse to the confluence with the Enguri River and establish if flood protection structures are required for normal operations.	Lo [-]	Downstream Flood Protection Plan: DOWN.1
	Downstream existing hydropower schemes affected by Nenskra reservoir operations	□	□	■	■	M [+] Certain. Long-term benefit for Enguri HPP through winter regulation	None	M [+]	
						Lo [-] Certain. Loss of inflow caused by the impoundment of the Nenskra reservoir represents 3.6 percent of the Enguri annual inflow	• [WAT 20] Coordination with GSE and Enguri HPP.	Lo [-]	Stakeholder Engagement Plan: PUB2.
	Powerhouse operated to meet daily demand for electricity as ordered by dispatch centre will result in daily variations of turbined flow.	□	□	□	■	Hi [-] Certain. Hourly variations throughout the year. In February – when the river flow is at its lowest – the peak energy turbining would cause the river flow downstream of the powerhouse to vary from 3 to 50 m3/s In June – when the river is at its highest – the peak energy turbining would cause river flow to vary between 24 and 70 m3/s. The 70 m3/s peak flow rate is 14% higher than the maximum yearly average monthly natural flow conditions.	• [WAT 15] Access restrictions and warning systems downstream of powerhouse • [WAT 16] Public awareness campaigns	M [-]	Emergency Action Plan: EAP 2. – EAP3.

Table 47 – Summary of impacts and commitments *(Continued)*

Environmental or Social Value	Impact Producing Factor	Phase: Early Works	Phase: Main construction	Phase: Reservoir Filling	Phase: Operation	Assessment of significance without mitigation or compensation High Hi - Moderate M - Low Lo [+] positive, [-] negative Likelihood, Magnitude, Extent, Duration	Commitments: Key Mitigation, Compensation or Management measures	Predicted residual impact	Management Action where the mitigation or compensation measure is addressed in the ESMP
Surface water hydrology (cont.)	Effective life of the Nenskra reservoir shortened because of trapping of sediments from soil erosion in catchment or from slopes through landslides and debris flow.	□	□	□	■	M [-] Probable. 0.185 million cubic metres per year of sediment will be trapped in the reservoir and which could reach the level of the bottom outlet after approximately 10 years of operation, and this making a key safety component unavailable.	• [WAT 37] Annual opening of bottom outlet is programmed during flood events.	Lo [-]	Water Quality Management: WQM3.
	Disruption of Nenskra river flow below dam during construction when the upstream cofferdam is built and river flow progressively diverted through the outlet intake.	□	■	□	□	Lo [-] Certain. The duration of the reduced Nenskra flow when filling the head pond upstream of the coffer dam depends on the season and the flow through the coffer dam culverts. With an inflow of 20 m3/s of which 10 m3/s is allowed to flow through the culverts, the time to fill the head pond is about 70 hours and Nenskra flow will be reduced to 50% of annual average	• [WAT 6] The Nenskra dam and coffer dam construction methods are adapted to ensure that the minimum ecological flow will be maintained at all times during construction with real-time monitoring and disclosure of the ecological flow on a website.	Lo [-]	Environmental Surveillance of Construction works: SURV.2
	Abstraction of river water to supply domestic water to the construction camp					Lo [-] Certain. Abstracted water will be negligible compared to river flow	• [WAT 11] Any water abstraction from tributaries of the Nenskra or Nakra Rivers subject to prior environmental review.	Lo [-]	Environmental Surveillance of Construction works: SURV.2
4Water quality	Earthworks adjacent/within riverbed or tunnel dewatering leading to increased sediment load and turbidity.	■	■	□	□	M [-] Certain. If no sediment control measures are put in place sediment from tunnel dewatering and runoff high in sediment from worksite and cleared areas will be transported into the Nenskra and Nakra Rivers.	• [WAT 25] Runoff and dewatering sediment control measures will be implemented using silt traps and runoff drainage channels. • [WAT 26] Temporary areas cleared of vegetation will be revegetated.		
	Contamination with accidental spillage, e.g. oils or other hazardous construction materials.	■	■	□	■	M [-] Probable. The extent of accidental pollution will depend on the volume of hazardous material spilt. The largest inventory will probably be hydrocarbons Hi [-] Possible. The extent of accidental pollution will depend on the volume of hazardous material spilt. The largest inventory will probably be hydrocarbons	• [WAT 33] Pollution prevention and protection plans and measures, including bunding of all inventories of hazardous materials, tank overfilling prevention measures.	Lo [-]	Environmental Surveillance of Construction works: SURV.2
	Risk of pollution from metal leaching and acid rock drainage from tunnel boring spoils containing sulphur bearing rocks.		■	■	■	Hi [-] Possible. Metal leaching and acid rock drainage from spoils could occur if sulphur bearing rocks are in the spoils. The extent of the pollution would depend on the quantities of sulphur and the metals present in the spoils	• [WAT 27] Preparation and implementation of an ARD and other geochemistry risk assessment programme for the tunnelling activities including definition of management of spoils representing an ARD risk or other geochemistry risks	Lo [-]	Environmental Surveillance of Construction works: SURV.2 Water Quality Management: WQM.1
	Waste water from the construction worker camps and run-off from technical platforms (e.g. batching plants) may cause pollution unless adequately treated.	■	■	□	□	Hi [-] Certain. The wastewater from the camp if untreated will most certainly cause noticeable changes in water quality and possibly affecting downstream water used as potable water by downstream communities	• [WAT 34] Construction work camp equipped with wastewater treatment plant with discharges compliant with IFC EHS guidelines. • [WAT 38] Water quality monitoring program.	Lo [-]	Environmental Surveillance of Construction works: SURV.2 Environmental Monitoring: MON.1
	Modification of water quality in Nenskra reservoir due to depletion of dissolved oxygen by decaying plant or to eutrophication, growth and proliferation of aquatic weeds.	□	□	■	■	M [-] Probable / short duration. Concentrations or nutrients and organic carbon are expected to be similar to that eutrophic reservoirs for the first 2 – 3 years after reservoir filling, but the high rate of reservoir recharge will flush out nutrients and concentrations will be similar to mesotrophic reservoirs and it is considered there is low risk of eutrophication	• [WAT 28] Reservoir vegetation clearing. • [WAT 29] Reservoir trees of commercial value transferred to local forestry authorities. • [WAT 30] Marketing of non-commercial trees cut from reservoir	M [-] Short duration	Water Quality Management: WQM.2 Environmental Surveillance of Construction works: SURV.2
	Modified water quality downstream of Nenskra dam and powerhouse due to water drawn from reservoir low water levels (environmental flow and power intake)	□	□	□	■	M [-] Probable / short duration. Concentrations or nutrients and organic carbon are expected to be high (similar to concentrations in a moderate eutrophic reservoir) in the first year after reservoir filling and then to decrease rapidly in subsequent years and to be close to baseline conditions after approximately 5 years	• [WAT 35] Small diversion weir design to allow by-pass • [WAT 36] Replace the ecological flow by the seasonal stream in case of modified water quality. • [WAT 38] Water quality monitoring program	M [-] Short duration	Environmental Surveillance of Construction works: SURV.1 Environmental Monitoring: MON.1
	Modified water quality downstream of Nakra diversion weir water due to water intake operation.	□	□	□	■	Lo [-] Certain. No discernible water quality issues expected	• [WAT 38] Water quality monitoring program	Lo [-]	Environmental Monitoring: MON.1

Table 47 - Summary of impacts and commitments *(Continued)*

Environmental or Social Value	Impact Producing Factor	Phase				Assessment of significance without mitigation or compensation High Hi - Moderate M - Low Lo [+] positive, [-] negative Likelihood, Magnitude, Extent, Duration	Commitments Key Mitigation, Compensation or Management measures	Predicted residual impact	Management Action where the mitigation or compensation measure is addressed in the ESMP
		Early Works	Main construction	Reservoir Filling	Operation				
Water quality (cont.)	Venting of sediments using bottom outlets and risk of downstream water quality degradation.	□	□	□	■	M [-] Probable/short duration. Short duration modified water quality issues are expected related to the venting of sediments. Sediments are not expected to be contaminated but venting will probably entrain downstream partly decomposed organic material high in nutrients and cause a plume of nutrients and suspended organic matter to pass down the river.	• [WAT 37] Annual opening of bottom outlet is programmed during flood events • [WAT 38] Water quality monitoring program • [WAT 17] Preparation of a sediment venting ESIA and implementation of recommended mitigation measures prior to the first opening of the bottom outlet for sediment venting purposes.	M [-] Short duration	Environmental Monitoring: MON.1 Environmental & Social Management System: ESMS.2
Groundwater	Ground water quality affected by accidental spillages of construction materials and oils. Solid waste disposal facilities could give rise to contamination of ground water.	□	■	□	□	Lo [-] Probable. No discernible downstream water quality issues expected because of the distance between the construction camps and local communities.	• [WAT 33] Pollution prevention and protection plans and measures, including bunding of all inventories of hazardous materials, tank overfilling prevention measures.	Lo [-]	Environmental Surveillance of Construction works: SURV.2
	Reduction of downstream river flow and impacts on water level in springs or wells	□	□	■	■	Lo [-] Unlikely. Most water supply systems rely on streams or seeps from slopes. Mineral waters springs are likely to be part of aquifers distinct from the Rivers.	• [WAT 21] Hydrological monitoring and real-time monitoring and disclosure on a website of the ecological flow.	Lo [-]	Environmental Monitoring: MON.2
Riverbed erosion & geomorphological changes	Increased erosion of river banks and bed downstream of powerhouse due to increased flows and daily variations	□	□	□	■	M [-] Possible. The changes in hydrology described above are not expected to cause erosion of the riverbed downstream from the powerhouse. However, there is a possibility that there will be some localised bank erosion along the 2 km reach immediately downstream from the powerhouse and upstream from the entrance to the gorge.	• [WAT 24] Monitoring of Nenskra River banks conditions downstream of powerhouse. Strengthening as and when required.	Lo [-]	Downstream Flood Protection Plan: DOWN 1.
	Erosion of riverbed below Nenskra dam due to release of turbidity-free waters	□	□	□	■	Lo [-] Unlikely. The reduced sediment input into the Nenskra will be offset by the reduced flow. The baseline situation is that the Nenskra has a capacity to transport sediment that is greater than the sediment present and this is reflected in the “armouring” of the river bed. The project is consequently not expected to cause a discernible erosion to riverbed	• [WAT 23] Geomorphological monitoring of the two rivers. • [WAT 22] Specialist study with regard to the evaluation and control of unstable Nenskra river bank slopes near the village of Kari.	Lo [-]	Downstream Flood Protection Plan: DOWN 1.
	Reduced bedload capacity of the Nenskra could reduce the capacity of the river to flush away accumulated sediments from debris flow and/or mudflow, hence creating natural dams.	□	□	□	■	Lo [-] Possible. Communities report that there are no reaches at risk of blockage from mudflows or debris flow. This was supported by visual observations by the assessment team. There are a few zones exposed to small areas of bank instability	• [WAT 23] Geomorphological monitoring of the two rivers.	Lo [-]	Downstream Flood Protection Plan: DOWN 1.
	Reduced bedload capacity of the Nakra could reduce the capacity of the river to flush away accumulated sediments from debris flow and/or mudflow, hence increasing likelihood of creating natural dams	□	□	□	■	Hi [-] Probable. In the past the Nakra River flushed away the material blocking the river. However, once the Nakra River is diverted to the Nenskra reservoir, the capacity of the river to flush away any material blocking the river will be significantly reduced. However, the reduced river flow even during a flood event will probably lengthen the time for the chain of natural events to occur. However, local communities will continue to be exposed to a flooding risk similar to that of the situation without the Project.	• [WAT 9] Maintain the sediment transport function of the Nakra River.	M [-]	Downstream Flood Protection Plan: DOWN 2.
Air and Climate	Greenhouse gas emissions produced during construction and operation but lower than those of similar-sized thermal plants.		■		■	M [+] Net GHG emissions are 2.3 million tonnes of CO2-eq over the construction period and 30 years of operation, of which the majority is from construction. The Project will result in a 9 percent reduction in the national emission intensity for electricity production. Reservoir emissions represent 51 thousand tonnes – produced in the first 7 years after reservoir filling. The reservoir emissions have been compared to benchmark indicators (reported by the World Commission on Dams) and the value of 32 g CO2-eq/ kWh which compares favourably with typical reservoir hydropower projects.	• [WAT 31] Biomass that is not of economic value is not to be burnt • [WAT 32] Solutions for soft biomass management will be identified	M [+]	Water Quality Management: WQM.3
	Micro-climate change around reservoir	□	□	□	■	Lo [-] Possible. Slightly localised increase in humidity and slightly lower temperatures in the summer months and slightly warmer temperatures in the autumn months. It is probable that any changes to the micro-climate will help attenuate the effects of climate change on a regional scale but will probably not be discernible to those impacts due to climate change	• [WAT 41] Project design includes microclimate monitoring stations in Dam site and in Chuberi.	Lo [-]	Stakeholder Engagement Plan: PUB2.

Annex 1. References

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Annex 2. Estimated quantities of above ground biomass in the reservoir area before vegetation clearing

The above ground biomass in the reservoir area before vegetation clearing has been estimated in order to estimate the quantities of understory biomass (shrubs and ground flora) which are potentially flooded. This information is used in the water quality calculations and the GHG emission calculations.

The quantities of biomass and nutrients have been estimated using the on-line biomass calculator made available by Natural Resources Canada[8] (Government of Canada). This is a simplified approach and provides an order of magnitude of biomass. However, this level of detail is sufficient as the purpose is to estimate the quantities of understory biomass which contain are only a small fraction of carbon and nutrients.

The assumptions and approach used in the calculations are outlined as follows:

- The estimation takes into account the dominant tree species and the area of trees flooded. The dominant tree species on the right bank of the reservoir is maple, and the dominant species on the left bank is beech. The flooded areas covered by each species – maple and beech are 79 hectares each. It is assumed for simplicity that the totality of each side of the flooded area is covered by maple and birch trees.
- The basal area of the trees – which is required in the calculation - is estimated to be 23 square metres per hectare, which corresponds to the average basal area for a fully stocked forest.

The calculation is provided in the table on the following page.

[8] https://apps-scf-cfs.rncan.gc.ca/calc/en/biomass-calculator

Table 48 – Nutrients and biomass in trees present in the reservoir area

	Bark	Branches	Foliage	Wood	Soft	Hard	Total
Biomass (kg/ha)							
Biomass (kg/ha) Maple	11,068	22,628	3,574	84,918	3,574	118,614	122,188
Biomass (kg/ha) Beech	7,747	35,882	3,227	114,273	3,227	157,902	161,129
Total biomass (kg)							
Total Biomass Maple	874,372	1,787,612	282,346	6,708,522	282,346	9,370,506	9,652,852
Total Biomass Beech	612,013	2,834,678	254,933	9,027,567	254,933	12,474,258	12,729,191
Nutrients in Beech forest (g/ha)							
N	58,103	107,646	76,478	213,310	76,478	379,059	455,537
P	3,099	41,264	4,931	7,618	4,931	51,981	56,912
K	101,873	304,997	27,346	81,420	27,346	488,290	515,636
Ca	126,844	125,587	22,799	102,617	22,799	355,048	377,847
Mg	3,486	46,647	5,682	20,569	5,682	70,702	76,384
Nutrients in Maple forest (g/ha)							
N	47,943	69,962	61,566	72,860	61,566	190,765	252,331
P	5,423	10,132	5,715	7,006	5,715	22,561	28,276
K	20,729	38,568	24,407	65,288	24,407	124,585	148,992
Ca	157,179	105,336	26,456	93,082	26,456	355,597	382,053
Mg	5,392	9,532	6,769	17,988	6,769	32,912	39,681
Nutrients in flooded Beech forest (kg)							
N	4,590	8,504	6,042	16,851	6,042	29,946	35,987
P	245	3,260	390	602	390	4,106	4,496
K	8,048	24,095	2,160	6,432	2,160	38,575	40,735
Ca	10,021	9,921	1,801	8,107	1,801	28,049	29,850
Mg	275	3,685	449	1,625	449	5,585	6,034
Nutrients in flooded maple forest (kg)							
N	3,787	5,527	4,864	5,756	4,864	15,070	19,934
P	428	800	451	553	451	1,782	2,234
K	1,638	3,047	1,928	5,158	1,928	9,842	11,770
Ca	12,417	8,322	2,090	7,353	2,090	28,092	30,182
Mg	426	753	535	1,421	535	2,600	3,135
Totals							
Total tree biomass (tonnes)	1,486	4,622	537	15,736	537	21,845	**22,382**
Total C (t)	743	2,311	269	7,868	269	10,922	11,191
Total N (kg)	8,378	14,031	10,905	22,607	10,905	45,016	55,922
Total P (kg)	673	4,060	841	1,155	841	5,889	6,730
Total K (kg)	9,686	27,142	4,088	11,590	4,088	48,417	52,506
Total Ca (kg)	22,438	18,243	3,891	15,460	3,891	56,141	60,032
Total Mg (kg)	701	4,438	984	3,046	984	8,186	9,169
Overall average biomass expressed in tonnes per hectare (= 22,382 tonnes biomass / (79 ha maple forest + 79 ha beech forest)							**142**

Annex 3. Water quality analysis records

THE NATIONAL ENVIRONMENTAL AGENCY
THE DEPARTMENT OF ENVIRONMENTAL POLLUTION MONITORING

ATMOSPHERIC AIR, WATER and SOIL ANALYSIS LABORATORY

8th Floor – David Agmashenebeli ave. 150, Tbilisi, Georgia O112

- Test report –
#96-2015

Registered sample number: #1057 - #1071

Number of Parties to the Protocol: 11

Name of customer: "World Experience for Georgia"

Address of customer: Vaja Pshavela av. VII, #17, Tbilisi, Georgia

Tel.: (+99532) 599 37-53-83

Identification of samples by the applicant: #1-#15

Description and identification of the sample (matrix): Surface water

Identification of the used method: Spectrophotometer, titrimetric, membrane filtration method

The date of receipt of the sample: 08.10.2015

The date of examination: 08.10.2015 –13.10.2015

Date of issue: 15.10.2015

#1057

SLR NAK-R-1

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	1.17	ISO 5815-1:2010
2	COD	mg/l	5.88	ISO 6060:2010
3	Total phosphorus	mg/l	1.283	Ю.Ю. Лурье "Унифицирова-нные методы анализа вод"
4	Total coliforms	in 300 ml	37	membrane filtration method
5	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1058

SLR NAK-R-2

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	0.72	ISO 5815-1:2010
2	COD	mg/l	3.92	ISO 6060:2010
3	Total phosphorus	mg/l	2.367	Ю.Ю. Лурье "Унифицирова-нные методы анализа вод"
4	Total coliforms	in 300 ml	41	membrane filtration method
5	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1059

SLR NAK-D-1

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	0.96	ISO 5815-1:2010
2	COD	mg/l	4.90	ISO 6060:2010
3	Total coliforms	in 300 ml	69	membrane filtration method
4	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1060

SLR NAK-S-1

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	3.83	ISO 5815-1:2010
2	COD	mg/l	1.76	ISO 6060:2010
3	Total coliforms	in 300 ml	45	membrane filtration method
4	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1061

SLR NAK-S-2

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	2.55	ISO 5815-1:2010
2	COD	mg/l	7.84	ISO 6060:2010
3	Total coliforms	in 300 ml	58	membrane filtration method
4	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1062

SLR NEN-R-1

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	0.85	ISO 5815-1:2010
2	COD	mg/l	3.92	ISO 6060:2010
3	Total phosphorus	mg/l	2.633	Ю.Ю. Лурье ”Унифицирова-нные методы анализа вод”
4	Total coliforms	in 300 ml	10	membrane filtration method
5	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1063

SLR NEN-R-2

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	0.95	ISO 5815-1:2010
2	COD	mg/l	5.68	ISO 6060:2010
3	Total phosphorus	mg/l	1.650	Ю.Ю. Лурье "Унифицирова-нные методы анализа вод"
4	Total coliforms	in 300 ml	65	membrane filtration method
5	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1064

SLR NEN-R-3

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	0.96	ISO 5815-1:2010
2	COD	mg/l	4.90	ISO 6060:2010
3	Total phosphorus	mg/l	2.967	Ю.Ю. Лурье "Унифицирова-нные методы анализа вод"
4	Total coliforms	in 300 ml	40	membrane filtration method
5	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1065

SLR NEN-S-1

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	2.73	ISO 5815-1:2010
2	COD	mg/l	13.72	ISO 6060:2010
3	Total coliforms	in 300 ml	32	membrane filtration method
4	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1066

SLR NEN-S-2

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	3.63	ISO 5815-1:2010
2	COD	mg/l	12.74	ISO 6060:2010
3	Total coliforms	in 300 ml	11	membrane filtration method
4	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1067

SLR NEN-S-3

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	0.95	ISO 5815-1:2010
2	COD	mg/l	7.64	ISO 6060:2010
3	Total coliforms	in 300 ml	22	membrane filtration method
4	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1068

SLR NEN-D-1

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	1.04	ISO 5815-1:2010
2	COD	mg/l	3.92	ISO 6060:2010
3	Total coliforms	in 300 ml	9	membrane filtration method
4	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1069

SLR NEN-D-2

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	0.99	ISO 5815-1:2010
2	COD	mg/l	5.88	ISO 6060:2010
3	Total coliforms	in 300 ml	4	membrane filtration method
4	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1070

SLR ENG-R-1

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	0.93	ISO 5815-1:2010
2	COD	mg/l	4.90	ISO 6060:2010
3	Total phosphorus	mg/l	2.750	Ю.Ю. Лурье ”Унифицирова-нные методы анализа вод”
4	Total coliforms	in 300 ml	27	membrane filtration method
5	Streptococcus facials	in 300 ml	N/D	membrane filtration method

#1071

SLR ENG-R-2

#	Measured Parameters	Unit	Results	Methods
1	BOD_5	mg/l	0.84	ISO 5815-1:2010
2	COD	mg/l	3.92	ISO 6060:2010
3	Total phosphorus	mg/l	3.183	Ю.Ю. Лурье ”Унифицирова-нные методы анализа вод”
4	Total coliforms	in 300 ml	49	membrane filtration method
5	Streptococcus facials	in 300 ml	N/D	membrane filtration method

Test results may be disputed in writing within 14 days from the date of receipt of the Protocol.

Executors:

G.Kuchava

M.Chigitashvili

M.Khvedeliani

L.Salamashvili

N.Korchilava

Head of laboratory: Elina Bakradze

ALcontrol B.V.
Adresse de correspondance
99-101 avenue Louis Roche · F-92230 Gennevilliers
Tel.: +33 (0)155 90 52 50 · Fax: +33 (0)155 90 52 51
www.alcontrol.fr

Rapport d'analyse

SLR CONSULTING France SAS
Bukowski
155-157 cours Berriat
38028 GRENOBLE

Votre nom de Projet	: Nenskra HPP Supplimentary E&s
Votre référence de Projet	: 901.00008.00001
Référence du rapport ALcontrol	: 12197493, version: 1

Rotterdam, 20-10-2015

Cher(e) Madame/ Monsieur,

Veuillez trouver ci-joint les résultats des analyses effectuées en laboratoire pour votre projet 901.00008.00001.
Le rapport reprend les descriptions des échantillons, le nom de projet et les analyses que vous avez indiqués sur le bon de commande. Les résultats rapportés se réfèrent uniquement aux échantillons analysés.

Ce rapport est constitué de 9 pages dont chromatogrammes si prévus, références normatives, informations sur les échantillons. Dans le cas d'une version 2 ou plus élevée, toute version antérieure n'est pas valable. Toutes les pages font partie intégrante de ce rapport, et seule une reproduction de l'ensemble du rapport est autorisée.

En cas de questions et/ou remarques concernant ce rapport, nous vous prions de contacter notre Service Client.

Toutes les analyses, à l'exception des analyses sous-traitées, sont réalisées par ALcontrol B.V., Steenhouwerstraat 15, Rotterdam, Pays Bas et / ou 99-101 Avenue Louis Roche, Gennevilliers, France.

Veuillez recevoir, Madame/ Monsieur, l'expression de nos cordiales salutations.

R. van Duin
Laboratory Manager

ALcontrol Laboratories

SLR CONSULTING France SAS
Bukowski Nicholas

Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&s	Date de commande	13-10-2015
Référence du projet	901.00008.00001	Date de début	13-10-2015
Réf. du rapport	12197493 - 1	Rapport du	20-10-2015

Code	Matrice	Réf. échantillon
001	Eau souterraine	NEN-S-1 (Nenskra mineral water spring 1)
002	Eau souterraine	NEN-S-2 (Nenskra mineral water spring 2)
003	Eau souterraine	NEN-S-3 (Nenskra drinking water spring 1)
004	Eau souterraine	NAK-S-1 (Nakra mineral water spring 1
005	Eau souterraine	NAK-S-2 (Nakra drinking water spring 1)

Analyse	Unité	Q	001	002	003	004	005
METAUX							
filtration métaux	-		1 [1)]	1 [1)]	1 [1)]	1 [1)]	1 [1)]
manganèse	µg/l	Q	1700 [1)]	6900 [1)]	<10 [1)]	11000 [1)]	<10 [1)]
COMPOSES ORGANO HALOGENES VOLATILS							
épichlorhydrine	µg/l		<5	<5	<5	<5	<5
CHLOROBENZENES							
hexachlorobenzène	µg/l	Q		<0.005	<0.005		
PESTICIDES CHLORES							
DDT total	µg/l			<0.02	<0.02		
o,p-DDT	µg/l	Q		<0.01	<0.01		
p,p-DDT	µg/l	Q		<0.01	<0.01		
DDD total	µg/l			<0.02	<0.02		
o,p-DDD	µg/l	Q		<0.01	<0.01		
p,p-DDD	µg/l	Q		<0.01	<0.01		
DDE total	µg/l			<0.02	<0.02		
o,p-DDE	µg/l	Q		<0.01	<0.01		
p,p-DDE	µg/l	Q		<0.01	<0.01		
DDT, DDE, DDD Totaux	µg/l			<0.06	<0.06		
aldrine	µg/l	Q		<0.01	<0.01		
dieldrine	µg/l	Q		<0.01	<0.01		
endrine	µg/l	Q		<0.01	<0.01		
aldrine/dieldrine totaux	µg/l			<0.02	<0.02		
drines totaux	µg/l			<0.03	<0.03		
télodrine	µg/l	Q		<0.03	<0.03		
isodrine	µg/l	Q		<0.03	<0.03		
alfa-HCH	µg/l	Q		<0.01	<0.01		
beta-HCH	µg/l	Q		<0.01	<0.01		
gamma-HCH	µg/l	Q		<0.01	<0.01		
delta-HCH	µg/l	Q		<0.02	<0.02		
HCH totaux	µg/l			<0.05	<0.05		
heptachlore	µg/l	Q		<0.01	<0.01		
cis-heptachlorépoxide	µg/l	Q		<0.01	<0.01		
trans-heptachlorépoxide	µg/l	Q		<0.01	<0.01		
heptachloroépoxydes totaux	µg/l			<0.02	<0.02		
alfa-endosulfane	µg/l	Q		<0.01	<0.01		
hexachlorobutadiène	µg/l	Q		<0.05	<0.05		
béta-endosulfane	µg/l	Q		<0.05	<0.05		
trans-chlordane	µg/l	Q		<0.01	<0.01		
cis-chlordane	µg/l	Q		<0.01	<0.01		

Les analyses notées Q sont accréditées par le RvA.

Paraphe :

ALcontrol Laboratories

SLR CONSULTING France SAS
Bukowski Nicholas

Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&s	Date de commande	13-10-2015
Référence du projet	901.00008.00001	Date de début	13-10-2015
Réf. du rapport	12197493 - 1	Rapport du	20-10-2015

Code	Matrice	Réf. échantillon
001	Eau souterraine	NEN-S-1 (Nenskra mineral water spring 1)
002	Eau souterraine	NEN-S-2 (Nenskra mineral water spring 2)
003	Eau souterraine	NEN-S-3 (Nenskra drinking water spring 1)
004	Eau souterraine	NAK-S-1 (Nakra mineral water spring 1
005	Eau souterraine	NAK-S-2 (Nakra drinking water spring 1)

Analyse	Unité	Q	001	002	003	004	005
quintozène	µg/l	Q		<0.05	<0.05		
drines totaux (5)	µg/l			<0.09	<0.09		
chlordane totaux	µg/l			<0.02	<0.02		
PESTICIDES PHOSPHORES							
dichlorvos	µg/l			<0.01	<0.01		
mevinphos (somme)	µg/l			<0.04	<0.04		
diméthoate	µg/l			<0.02	<0.02		
diazinon	µg/l			<0.01	<0.01		
disulphotone	µg/l			<0.01	<0.01		
parathione-méthyle	µg/l			<0.01	<0.01		
parathione-éthyle	µg/l			<0.01	<0.01		
malathion	µg/l			<0.01	<0.01		
phenthion	µg/l			<0.01	<0.01		
chloropyriphos-méthyle	µg/l			<0.02	<0.02		
chloropyriphos-éthyle	µg/l			<0.02	<0.02		
bromophos-méthyle	µg/l			<0.01	<0.01		
bromophos-éthyle	µg/l			<0.01	<0.01		
PESTICIDES AZOTES							
atrazine	µg/l			<0.03	<0.03		
propazine	µg/l			<0.01	<0.01		
simazine	µg/l			<0.01	<0.01		
terbutryne	µg/l			<0.01	<0.01		

Les analyses notées Q sont accréditées par le RvA.

Paraphe :

SLR CONSULTING France SAS
Bukowski Nicholas

Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&s	Date de commande	13-10-2015
Référence du projet	901.00008.00001	Date de début	13-10-2015
Réf. du rapport	12197493 - 1	Rapport du	20-10-2015

Commentaire

1	L'échantillon a été filtré au laboratoire

Paraphe :

ALcontrol Laboratories

SLR CONSULTING France SAS
Bukowski Nicholas

Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&s	Date de commande	13-10-2015
Référence du projet	901.00008.00001	Date de début	13-10-2015
Réf. du rapport	12197493 - 1	Rapport du	20-10-2015

Code	Matrice	Réf. échantillon
006	Eau souterraine	NEN-D-1 (Nenskra household drnking water 1)
007	Eau souterraine	NEN-D-2 (Nenskra household drinking water 2)
008	Eau souterraine	NAK-D-1 (Nakra household drinking water 1)

Analyse	Unité	Q	006	007	008
METAUX					
filtration métaux	-		1 [1)]	1 [1)]	1 [1)]
manganèse	µg/l	Q	<10 [1)]	<10 [1)]	<10 [1)]
COMPOSES ORGANO HALOGENES VOLATILS					
épichlorhydrine	µg/l		<5	<5	<5
CHLOROBENZENES					
hexachlorobenzène	µg/l	Q	<0.005	<0.005	
PESTICIDES CHLORES					
DDT total	µg/l		<0.02	<0.02	
o,p-DDT	µg/l	Q	<0.01	<0.01	
p,p-DDT	µg/l	Q	<0.01	<0.01	
DDD total	µg/l		<0.02	<0.02	
o,p-DDD	µg/l	Q	<0.01	<0.01	
p,p-DDD	µg/l	Q	<0.01	<0.01	
DDE total	µg/l		<0.02	<0.02	
o,p-DDE	µg/l	Q	<0.01	<0.01	
p,p-DDE	µg/l	Q	<0.01	<0.01	
DDT, DDE, DDD Totaux	µg/l		<0.06	<0.06	
aldrine	µg/l	Q	<0.01	<0.01	
dieldrine	µg/l	Q	<0.01	<0.01	
endrine	µg/l	Q	<0.01	<0.01	
aldrine/dieldrine totaux	µg/l		<0.02	<0.02	
drines totaux	µg/l		<0.03	<0.03	
télodrine	µg/l	Q	<0.03	<0.03	
isodrine	µg/l	Q	<0.03	<0.03	
alfa-HCH	µg/l	Q	<0.01	<0.01	
beta-HCH	µg/l	Q	<0.01	<0.01	
gamma-HCH	µg/l	Q	<0.01	<0.01	
delta-HCH	µg/l	Q	<0.02	<0.02	
HCH totaux	µg/l		<0.05	<0.05	
heptachlore	µg/l	Q	<0.01	<0.01	
cis-heptachlorépoxide	µg/l	Q	<0.01	<0.01	
trans-heptachlorépoxide	µg/l	Q	<0.01	<0.01	
heptachloroépoxydes totaux	µg/l		<0.02	<0.02	
alfa-endosulfane	µg/l	Q	<0.01	<0.01	
hexachlorobutadiène	µg/l	Q	<0.05	<0.05	
béta-endosulfane	µg/l	Q	<0.05	<0.05	
trans-chlordane	µg/l	Q	<0.01	<0.01	
cis-chlordane	µg/l	Q	<0.01	<0.01	
quintozène	µg/l	Q	<0.05	<0.05	
drines totaux (5)	µg/l		<0.09	<0.09	

Les analyses notées Q sont accréditées par le RvA.

Paraphe :

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Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&s	Date de commande	13-10-2015
Référence du projet	901.00008.00001	Date de début	13-10-2015
Réf. du rapport	12197493 - 1	Rapport du	20-10-2015

Code	Matrice	Réf. échantillon
006	Eau souterraine	NEN-D-1 (Nenskra household drnking water 1)
007	Eau souterraine	NEN-D-2 (Nenskra household drinking water 2)
008	Eau souterraine	NAK-D-1 (Nakra household drinking water 1)

Analyse	Unité	Q	006	007	008
chlordane totaux	µg/l		<0.02	<0.02	
PESTICIDES PHOSPHORES					
dichlorvos	µg/l		<0.01	<0.01	
mevinphos (somme)	µg/l		<0.04	<0.04	
diméthoate	µg/l		<0.02	<0.02	
diazinon	µg/l		<0.01	<0.01	
disulphotone	µg/l		<0.01	<0.01	
parathione-méthyle	µg/l		<0.01	<0.01	
parathione-éthyle	µg/l		<0.01	<0.01	
malathion	µg/l		<0.01	<0.01	
phenthion	µg/l		<0.01	<0.01	
chloropyriphos-méthyle	µg/l		<0.02	<0.02	
chloropyriphos-éthyle	µg/l		<0.02	<0.02	
bromophos-méthyle	µg/l		<0.01	<0.01	
bromophos-éthyle	µg/l		<0.01	<0.01	
PESTICIDES AZOTES					
atrazine	µg/l		<0.03	<0.03	
propazine	µg/l		<0.01	<0.01	
simazine	µg/l		<0.01	<0.01	
terbutryne	µg/l		<0.01	<0.01	

Paraphe :

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Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&s	Date de commande	13-10-2015
Référence du projet	901.00008.00001	Date de début	13-10-2015
Réf. du rapport	12197493 - 1	Rapport du	20-10-2015

Commentaire

1	L'échantillon a été filtré au laboratoire

Paraphe :

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Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&s	Date de commande	13-10-2015
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Analyse	Matrice	Référence normative
manganèse	Eau souterraine	Conforme à NEN 6966 et conforme à NEN-EN-ISO 11885
épichlorhydrine	Eau souterraine	Méthode interne, headspace GCMS
hexachlorobenzène	Eau souterraine	Méthode interne, LVI GCMS
o,p-DDT	Eau souterraine	Idem
p,p-DDT	Eau souterraine	Idem
o,p-DDD	Eau souterraine	Idem
p,p-DDD	Eau souterraine	Idem
o,p-DDE	Eau souterraine	Idem
p,p-DDE	Eau souterraine	Idem
DDT, DDE, DDD Totaux	Eau souterraine	Idem
aldrine	Eau souterraine	Idem
dieldrine	Eau souterraine	Idem
endrine	Eau souterraine	Idem
télodrine	Eau souterraine	Idem
isodrine	Eau souterraine	Idem
alfa-HCH	Eau souterraine	Idem
beta-HCH	Eau souterraine	Idem
gamma-HCH	Eau souterraine	Idem
delta-HCH	Eau souterraine	Idem
HCH totaux	Eau souterraine	Idem
heptachlore	Eau souterraine	Idem
cis-heptachlorépoxide	Eau souterraine	Idem
trans-heptachlorépoxide	Eau souterraine	Idem
alfa-endosulfane	Eau souterraine	Idem
hexachlorobutadiène	Eau souterraine	Idem
béta-endosulfane	Eau souterraine	Idem
trans-chlordane	Eau souterraine	Idem
cis-chlordane	Eau souterraine	Idem
quintozène	Eau souterraine	Idem
dichlorvos	Eau souterraine	Idem
mevinphos (somme)	Eau souterraine	Idem
diméthoate	Eau souterraine	Idem
diazinon	Eau souterraine	Idem
disulphotone	Eau souterraine	Idem
parathione-méthyle	Eau souterraine	Idem
parathione-éthyle	Eau souterraine	Idem
malathion	Eau souterraine	Idem
phenthion	Eau souterraine	Idem
chloropyriphos-méthyle	Eau souterraine	Idem
chloropyriphos-éthyle	Eau souterraine	Idem
bromophos-méthyle	Eau souterraine	Idem
bromophos-éthyle	Eau souterraine	Idem
atrazine	Eau souterraine	Idem
propazine	Eau souterraine	Idem
simazine	Eau souterraine	Idem
terbutryne	Eau souterraine	Idem

Code	Code barres	Date de réception	Date prelèvement	Flaconnage	
001	B5744934	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
001	G8942627	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique

Paraphe :

Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&s	Date de commande	13-10-2015
Référence du projet	901.00008.00001	Date de début	13-10-2015
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Code	Code barres	Date de réception	Date prelèvement	Flaconnage	
001	B5744935	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
001	S0750357	12-10-2015	12-10-2015	ALC237	Date de prélèvement théorique
002	B5744918	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
002	S0750350	12-10-2015	12-10-2015	ALC237	Date de prélèvement théorique
002	G8942658	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
002	B5744911	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
003	B5744906	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
003	G8942623	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
003	B5744930	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
003	S0750233	12-10-2015	12-10-2015	ALC237	Date de prélèvement théorique
004	G8942640	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
004	B5744927	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
004	B5744926	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
005	B5744919	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
005	G8942632	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
005	B5744914	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
006	G8942635	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
006	B5744905	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
006	S0799713	12-10-2015	12-10-2015	ALC237	Date de prélèvement théorique
006	B5744893	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
007	G8942629	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
007	B5744925	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
007	G8942630	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
007	B5744932	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
008	B5744903	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
008	G8942645	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
008	B5744901	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique

Paraphe :

ALcontrol B.V.
Adresse de correspondance
99-101 avenue Louis Roche · F-92230 Gennevilliers
Tel.: +33 (0)155 90 52 50 · Fax: +33 (0)155 90 52 51
www.alcontrol.fr

Rapport d'analyse

SLR CONSULTING France SAS
Bukowski
155-157 cours Berriat
38028 GRENOBLE

Votre nom de Projet	: Nenskra HPP Supplimentary E&S
Votre référence de Projet	: 901.00008.00001
Référence du rapport ALcontrol	: 12197456, version: 1

Rotterdam, 20-10-2015

Cher(e) Madame/ Monsieur,

Veuillez trouver ci-joint les résultats des analyses effectuées en laboratoire pour votre projet 901.00008.00001.
Le rapport reprend les descriptions des échantillons, le nom de projet et les analyses que vous avez indiqués sur le bon de commande. Les résultats rapportés se réfèrent uniquement aux échantillons analysés.

Ce rapport est constitué de 5 pages dont chromatogrammes si prévus, références normatives, informations sur les échantillons. Dans le cas d'une version 2 ou plus élevée, toute version antérieure n'est pas valable. Toutes les pages font partie intégrante de ce rapport, et seule une reproduction de l'ensemble du rapport est autorisée.

En cas de questions et/ou remarques concernant ce rapport, nous vous prions de contacter notre Service Client.

Toutes les analyses, à l'exception des analyses sous-traitées, sont réalisées par ALcontrol B.V., Steenhouwerstraat 15, Rotterdam, Pays Bas et / ou 99-101 Avenue Louis Roche, Gennevilliers, France.

Veuillez recevoir, Madame/ Monsieur, l'expression de nos cordiales salutations.

R. van Duin
Laboratory Manager

ALcontrol Laboratories

SLR CONSULTING France SAS
Bukowski Nicholas

Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&S	Date de commande	13-10-2015
Référence du projet	901.00008.00001	Date de début	13-10-2015
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Code	Matrice	Réf. échantillon
001	Eau de surface	NEN-R-1 (Nenskra river sample 1)
002	Eau de surface	NEN-R-2 (Nenskra river sample 2)
003	Eau de surface	NEN-R-3 (Nenskra river sample 3)
004	Eau de surface	NAK_R-1 (Nakra river sample 1)
005	Eau de surface	NAK-R-2 (Nakra river sample 2)

Analyse	Unité	Q	001	002	003	004	005
COT	mg/l	Q	<0.5	<0.5	0.50	0.51	0.69
METAUX							
dureté calcium	meq/l		0.36	0.46	0.54	0.69	0.65
mercure	µg/l	Q	<0.05	<0.05	<0.05	<0.05	<0.05
dureté magnésium	meq/l		0.16	0.2	0.25	0.25	0.24
Dureté (TH)	meq/l		0.5	0.7	0.8	0.9	0.9
dureté totale	deg. all		1.5	1.8	2.2	2.6	2.5
COMPOSES INORGANIQUES							
ammonium	mg/l	Q	<0.2	<0.2	<0.2	<0.2	<0.2
ammonium	mgN/l	Q	<0.15	<0.15	<0.15	<0.15	<0.15
phosphore	µg/l	Q	<50	<50	<50	<50	<50
AUTRES ANALYSES CHIMIQUES							
chlorures	mg/l	Q	<3.0	<3.0	<3.0	<3.0	<3.0
nitrite	mg/l	Q	<0.3	<0.3	<0.3	<0.3	<0.3
nitrite	mgN/l	Q	<0.1	<0.1	<0.1	<0.1	<0.1
nitrate	mg/l	Q	<0.75	<0.75	<0.75	0.81	0.83
nitrate	mgN/l	Q	<0.17	<0.17	<0.17	0.18	0.19
sulfate	mg/l	Q	8.8	8.7	9.6	10	10
(ortho)phosphates	mgP/l	Q	<0.05	<0.05	<0.05	<0.05	<0.05
Alcalinité (en CaCO3)	mg CaCO3/l		<25	<25	29	33	35
Alcalinité (TAC en meq/l)	meq/l		<0.5	<0.5	0.6	0.7	0.7

Les analyses notées Q sont accréditées par le RvA.

Paraphe :

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Bukowski Nicholas

Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&S	Date de commande	13-10-2015
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Code	Matrice	Réf. échantillon
006	Eau de surface	ENG-R-1 (Enguri river sample 1)
007	Eau de surface	ENG-R-2 (Enguri river sample 2)

Analyse	Unité	Q	006	007
COT	mg/l	Q	<0.5	0.79
METAUX				
dureté calcium	meq/l		1.0	0.95
mercure	µg/l	Q	<0.05	<0.05
dureté magnésium	meq/l		0.52	0.49
Dureté (TH)	meq/l		1.5	1.4
dureté totale	deg. all		4.3	4.1
COMPOSES INORGANIQUES				
ammonium	mg/l	Q	<0.2	<0.2
ammonium	mgN/l	Q	<0.15	<0.15
phosphore	µg/l	Q	<50	<50
AUTRES ANALYSES CHIMIQUES				
chlorures	mg/l	Q	<3.0	<3.0
nitrite	mg/l	Q	<0.3	<0.3
nitrite	mgN/l	Q	<0.1	<0.1
nitrate	mg/l	Q	0.81	0.75
nitrate	mgN/l	Q	0.18	<0.17
sulfate	mg/l	Q	21	19
(ortho)phosphates	mgP/l	Q	<0.05	<0.05
Alcalinité (en CaCO3)	mg CaCO3/l		50	46
Alcalinité (TAC en meq/l)	meq/l		1.0	0.9

Les analyses notées Q sont accréditées par le RvA.

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Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&S	Date de commande	13-10-2015
Référence du projet	901.00008.00001	Date de début	13-10-2015
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Analyse	Matrice	Référence normative
COT	Eau de surface	Conforme à NEN-EN 1484
dureté calcium	Eau de surface	Méthode interne
mercure	Eau de surface	Conforme à NEN-EN-ISO 17852
dureté magnésium	Eau de surface	Méthode interne
Dureté (TH)	Eau de surface	Idem
dureté totale	Eau de surface	Idem
ammonium	Eau de surface	Conforme à NEN-ISO 15923-1
ammonium	Eau de surface	Idem
phosphore	Eau de surface	Conforme à NEN 6966 et conforme à NEN-EN-ISO 11885
chlorures	Eau de surface	Conforme à NEN-ISO 15923-1
nitrite	Eau de surface	Idem
nitrate	Eau de surface	Idem
nitrate	Eau de surface	Idem
sulfate	Eau de surface	Idem
(ortho)phosphates	Eau de surface	Idem
Alcalinité (en CaCO3)	Eau de surface	Méthode interne
Alcalinité (TAC en meq/l)	Eau de surface	Idem

Code	Code barres	Date de réception	Date prelèvement	Flaconnage	
001	B5744898	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
001	B5748074	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
001	T0185203	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
001	G8942616	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
001	B5744892	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
002	B5748073	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
002	G8942634	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
002	B5744936	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
002	B5748067	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
002	T0185210	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
003	B5744897	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
003	B5744902	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
003	G8942628	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
003	T0185204	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
003	B5744921	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
004	B5744933	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
004	B5744913	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
004	T0185207	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
004	B5744907	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
004	G8942647	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
005	B5744915	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
005	B5744894	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
005	G8942639	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
005	B5744895	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
005	T0185211	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
006	B5744908	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
006	G8942622	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
006	B5748075	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique

Paraphe :

Rapport d'analyse

Projet	Nenskra HPP Supplimentary E&S	Date de commande	13-10-2015
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Code	Code barres	Date de réception	Date prelèvement	Flaconnage	
006	B5744910	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
006	T0185181	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
007	B5744904	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
007	B5744916	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
007	T0185206	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
007	G8690527	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
007	B5744896	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique

Paraphe :

ALcontrol B.V.
Adresse de correspondance
99-101 avenue Louis Roche · F-92230 Gennevilliers
Tel.: +33 (0)155 90 52 50 · Fax: +33 (0)155 90 52 51
www.alcontrol.fr

Rapport d'analyse

SLR CONSULTING France SAS
Bukowski
155-157 cours Berriat
38028 GRENOBLE

Votre nom de Projet	: Nenskra HPP Suplimentary E&S
Votre référence de Projet	: 901.00008.00001
Référence du rapport ALcontrol	: 12197481, version: 1

Rotterdam, 20-10-2015

Cher(e) Madame/ Monsieur,

Veuillez trouver ci-joint les résultats des analyses effectuées en laboratoire pour votre projet 901.00008.00001.
Le rapport reprend les descriptions des échantillons, le nom de projet et les analyses que vous avez indiqués sur le bon de commande. Les résultats rapportés se réfèrent uniquement aux échantillons analysés.

Ce rapport est constitué de 7 pages dont chromatogrammes si prévus, références normatives, informations sur les échantillons. Dans le cas d'une version 2 ou plus élevée, toute version antérieure n'est pas valable. Toutes les pages font partie intégrante de ce rapport, et seule une reproduction de l'ensemble du rapport est autorisée.

En cas de questions et/ou remarques concernant ce rapport, nous vous prions de contacter notre Service Client.

Toutes les analyses, à l'exception des analyses sous-traitées, sont réalisées par ALcontrol B.V., Steenhouwerstraat 15, Rotterdam, Pays Bas et / ou 99-101 Avenue Louis Roche, Gennevilliers, France.

Veuillez recevoir, Madame/ Monsieur, l'expression de nos cordiales salutations.

R. van Duin
Laboratory Manager

ALcontrol Laboratories

SLR CONSULTING France SAS
Bukowski Nicholas

Rapport d'analyse

Projet	Nenskra HPP Suplimentary E&S	Date de commande	13-10-2015
Référence du projet	901.00008.00001	Date de début	13-10-2015
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Code	Matrice	Réf. échantillon
001	Eau souterraine	NEN-S-1 (Nenskra mieral water spring 1)
002	Eau souterraine	NEN-S-2 (Nenskra mineral water spring 2)
003	Eau souterraine	NEN-S-3 (Nenskra drinking water spring 1)
004	Eau souterraine	NAK-S-1 (Nakra mineral water spring 1)
005	Eau souterraine	NAK-S-2 (Nakra drinking water spring 1)

Analyse	Unité	Q	001	002	003	004	005
COT	mg/l	Q	1.2	<0.5	<0.5	1.7 [2]	0.84 [2]
METAUX							
filtration métaux	-		1 [1]	1 [1]	1 [1]	1 [1]	1 [1]
aluminium	µg/l	Q	<50 [1]	<50 [1]	<50 [1]	<50 [1]	<50 [1]
antimoine	µg/l	Q	<2.0 [1]	<2.0 [1]	<2.0 [1]	<2.0 [1]	<2.0 [1]
arsenic	µg/l	Q	26 [1]	24 [1]	<5 [1]	30 [1]	<5 [1]
baryum	µg/l	Q	180 [1]	140 [1]	<15 [1]	63 [1]	<15 [1]
bore	µg/l	Q	7700 [1]	2600 [1]	<50 [1]	10000 [1]	<50 [1]
cadmium	µg/l	Q	0.21 [1]	<0.20 [1]	<0.20 [1]	0.56 [1]	<0.20 [1]
durété calcium	meq/l		16 [1]	7 [1]	1 [1]	12 [1]	1 [1]
chrome	µg/l	Q	<1 [1]	<1 [1]	<1 [1]	<1 [1]	<1 [1]
cuivre	µg/l	Q	<2.0 [1]	<2.0 [1]	<2.0 [1]	<2.0 [1]	<2.0 [1]
mercure	µg/l	Q	<0.05 [1]	<0.05 [1]	<0.05 [1]	<0.05 [1]	<0.05 [1]
plomb	µg/l	Q	2.9 [1]	3.8 [1]	<2.0 [1]	5.1 [1]	<2.0 [1]
dureté magnésium	meq/l		5.8 [1]	4.2 [1]	0.85 [1]	4.3 [1]	0.28 [1]
molybdène	µg/l	Q	<2 [1]	<2 [1]	<2 [1]	<2 [1]	<2 [1]
nickel	µg/l	Q	6.2 [1]	<3 [1]	<3 [1]	18 [1]	<3 [1]
sélénium	µg/l	Q	29 [1]	12 [1]	<3.9 [1]	29 [1]	<3.9 [1]
fer	µg/l	Q	2200 [1]	64 [1]	<50 [1]	<50 [1]	<50 [1]
zinc	µg/l	Q	14 [1]	<10 [1]	15 [1]	17 [1]	<10 [1]
Dureté (TH)	meq/l		22 [1]	12 [1]	2.0 [1]	16 [1]	1.3 [1]
dureté totale	deg. all		62	32	5.7	45	3.6
COMPOSES INORGANIQUES							
ammonium	mg/l	Q	0.7	0.2	<0.2	<0.2	<0.2
ammonium	mgN/l	Q	0.5	0.2	<0.15	<0.15	<0.15
fluorures	mg/l	Q	0.56	0.56	<0.2	<0.2	<0.2
AUTRES ANALYSES CHIMIQUES							
chlorures	mg/l	Q	56	60	<3.0	58	<3.0
nitrite	mg/l	Q	<0.3	<0.3	<0.3	<0.3	<0.3
nitrite	mgN/l	Q	<0.1	<0.1	<0.1	<0.1	<0.1
nitrate	mg/l	Q	<0.75	<0.75	2.0	<0.75	<0.75
nitrate	mgN/l	Q	<0.17	<0.17	0.44	<0.17	<0.17
sulfate	mg/l	Q	25	13	16	47	9.1
Alcalinité (en CaCO3)	mg CaCO3/l		1300	950	80	1400	43
Alcalinité (TAC en meq/l)	meq/l		26	19	1.6	28	0.9

Les analyses notées Q sont accréditées par le RvA.

Paraphe :

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SLR CONSULTING France SAS
Bukowski Nicholas

Rapport d'analyse

Projet	Nenskra HPP Suplimentary E&S	Date de commande	13-10-2015
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Commentaire

1	L'échantillon a été filtré au laboratoire
2	Les propriétés de l'échantillon et/ou le flaconnage utilisé impliquent que l'échantillon n'était pas à un pH assez faible à son arrivée au laboratoire, suivant la norme NF-EN-ISO 5667-3. De l'acide a été ajouté. Les résultats sont néanmoins indicatifs.

Paraphe :

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Rapport d'analyse

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Code	Matrice	Réf. échantillon
006	Eau souterraine	NEN-D-1 (Nenskra household driking water 1)
007	Eau souterraine	NEN-D-2 (Nenskra household driking water 2)
008	Eau souterraine	NAK-D-1 (Nakra household drinking water 1)

Analyse	Unité	Q	006	007	008
COT	mg/l	Q	<0.5	<0.5	<0.5
METAUX					
filtration métaux	-		1 [1)]	1 [1)]	1 [1)]
aluminium	µg/l	Q	<50 [1)]	<50 [1)]	<50 [1)]
antimoine	µg/l	Q	<2.0 [1)]	<2.0 [1)]	<2.0 [1)]
arsenic	µg/l	Q	<5 [1)]	<5 [1)]	<5 [1)]
baryum	µg/l	Q	<15 [1)]	<15 [1)]	<15 [1)]
bore	µg/l	Q	<50 [1)]	<50 [1)]	<50 [1)]
cadmium	µg/l	Q	<0.20 [1)]	<0.20 [1)]	<0.20 [1)]
duréte calcium	meq/l		1 [1)]	1 [1)]	1 [1)]
chrome	µg/l	Q	<1 [1)]	<1 [1)]	<1 [1)]
cuivre	µg/l	Q	<2.0 [1)]	<2.0 [1)]	<2.0 [1)]
mercure	µg/l	Q	<0.05 [1)]	<0.05 [1)]	<0.05 [1)]
plomb	µg/l	Q	<2.0 [1)]	<2.0 [1)]	<2.0 [1)]
dureté magnésium	meq/l		0.65 [1)]	1.0 [1)]	0.77 [1)]
molybdène	µg/l	Q	<2 [1)]	<2 [1)]	<2 [1)]
nickel	µg/l	Q	<3 [1)]	<3 [1)]	<3 [1)]
sélénium	µg/l	Q	<3.9 [1)]	<3.9 [1)]	<3.9 [1)]
fer	µg/l	Q	<50 [1)]	<50 [1)]	<50 [1)]
zinc	µg/l	Q	<10 [1)]	<10 [1)]	<10 [1)]
Dureté (TH)	meq/l		2.1 [1)]	2.5 [1)]	2.1 [1)]
dureté totale	deg. all		5.9	6.9	5.8
COMPOSES INORGANIQUES					
ammonium	mg/l	Q	<0.2	<0.2	<0.2
ammonium	mgN/l	Q	<0.15	<0.15	<0.15
fluorures	mg/l	Q	<0.2	<0.2	<0.2
AUTRES ANALYSES CHIMIQUES					
chlorures	mg/l	Q	<3.0	<3.0	<3.0
nitrite	mg/l	Q	<0.3	<0.3	<0.3
nitrite	mgN/l	Q	<0.1	<0.1	<0.1
nitrate	mg/l	Q	0.96	0.98	1.4
nitrate	mgN/l	Q	0.22	0.22	0.32
sulfate	mg/l	Q	13	18	11
Alcalinité (en CaCO3)	mg CaCO3/l		79	97	78
Alcalinité (TAC en meq/l)	meq/l		1.6	1.9	1.6

Les analyses notées Q sont accréditées par le RvA.

Paraphe :

Rapport d'analyse

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Commentaire

1 L'échantillon a été filtré au laboratoire

Paraphe :

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Analyse	Matrice	Référence normative
COT	Eau souterraine	Conforme à NEN-EN 1484
aluminium	Eau souterraine	Conforme à NEN 6966 et conforme à NEN-EN-ISO 11885
antimoine	Eau souterraine	Idem
arsenic	Eau souterraine	Idem
baryum	Eau souterraine	Idem
bore	Eau souterraine	Idem
cadmium	Eau souterraine	Idem
durété calcium	Eau souterraine	Méthode interne
chrome	Eau souterraine	Conforme à NEN 6966 et conforme à NEN-EN-ISO 11885
cuivre	Eau souterraine	Idem
mercure	Eau souterraine	Conforme à NEN-EN-ISO 17852
plomb	Eau souterraine	Conforme à NEN 6966 et conforme à NEN-EN-ISO 11885
dureté magnésium	Eau souterraine	Méthode interne
molybdène	Eau souterraine	Conforme à NEN 6966 et conforme à NEN-EN-ISO 11885
nickel	Eau souterraine	Idem
sélénium	Eau souterraine	Idem
fer	Eau souterraine	Idem
zinc	Eau souterraine	Idem
Dureté (TH)	Eau souterraine	Méthode interne
dureté totale	Eau souterraine	Idem
ammonium	Eau souterraine	Conforme à NEN-ISO 15923-1
ammonium	Eau souterraine	Idem
fluorures	Eau souterraine	Conforme à NEN-EN-IS0 10304-1
chlorures	Eau souterraine	Conforme à NEN-ISO 15923-1
nitrite	Eau souterraine	Idem
nitrate	Eau souterraine	Idem
nitrate	Eau souterraine	Idem
sulfate	Eau souterraine	Idem
Alcalinité (en CaCO3)	Eau souterraine	Méthode interne
Alcalinité (TAC en meq/l)	Eau souterraine	Idem

Code	Code barres	Date de réception	Date prelèvement	Flaconnage	
001	S0750357	12-10-2015	12-10-2015	ALC237	Date de prélèvement théorique
001	B5744934	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
001	B5744935	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
001	G8942652	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
001	B5744923	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
001	B5744929	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
001	T0185182	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
001	G8942627	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
002	T0185205	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
002	B5744917	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
002	B5744918	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
002	G8942658	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
002	G8942624	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
002	B5744911	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
002	S0750350	12-10-2015	12-10-2015	ALC237	Date de prélèvement théorique
002	B5744912	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique

Paraphe :

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Code	Code barres	Date de réception	Date prelèvement	Flaconnage	
003	S0750233	12-10-2015	12-10-2015	ALC237	Date de prélèvement théorique
003	G8942623	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
003	B5748068	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
003	B5744930	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
003	B5744906	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
003	G8942651	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
003	T0185212	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
003	B5744924	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
004	B5744927	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
004	B5744909	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
004	G8690528	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
004	B5744922	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
004	B5744926	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
004	T0185202	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
004	G8942640	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
005	B5744919	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
005	B5744914	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
005	B5744900	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
005	G8942646	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
005	B5744920	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
005	T0185201	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
005	G8942632	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
006	S0799713	12-10-2015	12-10-2015	ALC237	Date de prélèvement théorique
006	T0185209	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
006	B5744905	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
006	B5744928	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
006	G8942653	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
006	B5744899	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
006	B5744893	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
006	G8942635	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
007	B5744931	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
007	B5744937	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
007	T0185188	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
007	B5744925	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
007	B5744932	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
007	G8942630	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
007	G8942629	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
007	G8942641	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
008	G8942645	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
008	T0185208	12-10-2015	12-10-2015	ALC244	Date de prélèvement théorique
008	B5744939	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
008	B5744938	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
008	G8942633	12-10-2015	12-10-2015	ALC236	Date de prélèvement théorique
008	B5744903	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique
008	B5744901	12-10-2015	12-10-2015	ALC207	Date de prélèvement théorique

Paraphe :

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global environmental solutions

Industry

Infrastructure

Mining & Minerals

Oil & Gas

Planning & Development

Renewable & Low Carbon

Waste Management