No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF AGRICULTURE FORESTRY AND WATER ECONOMY (MAFWE)
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

THE STUDY ON CAPACITY DEVELOPMENT FOR SOIL CONTAMINATION MANAGEMENT RELATED TO MINING IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

FINAL REPORT
VOLUME V
ACTION PLAN OF RISK MITIGATION FOR SOIL CONTAMINATION IN THE PILOT PROJECT AREA

MARCH 2008

MITSUBISHI MATERIALS NATURAL RESOURCES DEVELOPMENT CORPORATION

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PREFACE

The Action Plan for the Pilot Project area was formulated as a part of work of the Pilot Project of "Study on capacity development for soil contamination management related to mining in the Former Yugoslav Republic of Macedonia". The purpose of the Action Plan is to implement appropriate remedial measures against the soil contamination in the Pilot Project area based on the results of the Pilot Project survey and to recommend suitable land use in the area for mitigating the risks of harmful heavy metals related to the mining.

Since the Action Plan is basically to remediate the soil contamination in the P/P area of Probistip, it was developed and formulated by the working Group consisting of not only the JICA Study Team and Ministry of Agriculture Forestry and Water Economy as main counterpart, but also other relevant organizations to the soil contamination management and stakeholders, including the Ministry of Environment and Physical Planning, the Hydro-System Zletovica (HSZ) and Probistip Municipality.

We would like to thank all the concerned persons of the Ministry of Agriculture Forestry and Water Economy, Ministry of Environment and Physical Planning, Ministry of Economy, and Probistip Municipality, for their regular advice and co-operation.

March 2008

FORMATION OF THE FINAL REPORT

The Final Report is comprised of the following volumes:

Volume I	:	SUMMARY
Volume II	:	MAIN REPORT
Volume III	:	APPENDICES
Volume IV	:	DATA REPORT
Volume V	:	ACTION PLAN OF RISK MITIGATION FOR SOIL CONTAMINATION IN THE PILOT PROJECT AREA
Volume VI	:	SUMMARY (in Japanese)

Volume I, SUMMARY, contains background information of the study, brief information of the Pilot Project and summary of the Master Plan for soil contamination management related to mining in Macedonia.

Volume II, MAIN REPORT, contains information of the overall study and its results; that is the background information of this study, results of the Pilot Project and the Master Plan for soil contamination management related to mining in Macedonia.

Volume III, APPENDICES, contains figures related to the main report and some explanation materials.

Volume IV, DATA REPORT, contains various material supporting the report, such as sampling methods, methods of chemical analysis, descriptions of soil and drilling core, results of chemical analysis, calculation and distribution of environmental risk in the Pilot Project Area and minute of the steering and technical committees and working groups.

Volume V, ACTION PLAN OF RISK MITIGATION FOR SOIL CONTAMINATION IN THE PILOT PROJECT AREA, contains the action plan for the soil contamination in the Pilot Project Area.

Volume VI, Summary in Japanese

ABSTRACT

The Action Plan for the Pilot Project (P/P) area is one of the results of the "Study on capacity development for soil contamination management related to mining in the Former Yugoslav Republic of Macedonia", and it was specifically developed concerning the land use of the soil contaminated area.

The purpose of the Action Plan is to implement appropriate remedial measures against the soil contamination in the area, based on the results of the P/P survey, and to recommend suitable land use in the area for mitigating the risks of harmful heavy metals related to the mining.

This Action Plan has been developed in co-operation with a Working Group of specialists from the Ministry of Agriculture (MAFWE), Probistip Municipality, Ministry of Environment and Physical Planning (MEPP) and the Hydro System Zletovica (HSZ). The actions in this document include both of technical and management countermeasures to mitigate the soil contamination in Probistip Municipality. The actions have been developed based on the results of the P/P survey on soil contamination.

- The purpose of the Action Plan is to implement appropriate remedial measures against the soil contamination in the area based on the results of the P/P survey, and to recommend suitable land use in the area for mitigating the risks of harmful heavy metals related to the mining.
- The objective area of the Action Plan is the area of 400m grid soil survey in the P/P area, which is located in the Zletovica Basin in Probistip. The content of the Action Plan mainly consists of 1) review of the P/P survey, 2) Risk assessment of heavy metals, 3) remedial counter-measures for soil contamination, and 4) implementation of the plan.

1. Pilot Project

The purpose of the Pilot Project (P/P) was to understand the situation of soil contamination of the P/P area and to implement capacity development for management of soil contamination to governmental institutions and local organisations.

1.1 Survey Results of the Pilot Project

The grid soil surveys at the grid sizes of 400m, 200m, 100m and 50m, successively conducted in the P/P Area, resulted in identifying zones of high concentrations of heavy metals, narrow-downing the zones and clearly defining the boundaries of lower and higher concentration zones. The high heavy metal concentration zones from human and natural causes were clarified by the soil survey. The high concentration zones of Cd-Cu-Pb-Zn-Mn, occurring along the Kiselica River and lower stream area of the Zletovska River, can be attributed to the spillage of the tailings by the accidents of collapse of the tailings dam in 1976. Other high concentration zones of Cd-Cu-Pb-Zn-Mn, found

along the Koritnica River and Zletovska River before the Kiselica River flows in, can be attributed to the mining activity of the Zletovo mine site. The two occurrences of high heavy metal concentrations are considered to be caused by mining activities of the area, therefore considered as contamination by human causes. A wide distribution of high Co-Cr-Ni grids in the southwest of the area corresponds well with a distribution of the Eocene sedimentary rock, and the cause of the Co-Cr-Ni enrichment in soil of the area is attributed to geological nature (natural cause). High As concentration zone occurs overlapping and close to high Cd-Cu-Pb-Zn-Mn zone in the tailing dam area and the other ones occur isolated in the area south of the Probistip, northwest and northeast of the P/P Area. The former is clearly related to the mining activities of the area and the latter are most probably related to the natural causes, caused by the mineralization of Pb-Zn.

The well/spring water samples collected from the 29 villages of the P/P area show high concentrations of As, Co, Ni and Pb, being higher than the Standard of Drinking Water in most of the wells and springs. It is a serious health problem that more than half of the wells/springs in the P/P area are still used as a source of drinking water by the local residents. The situation of river water is similar, showing the Ni, Pb and Mn concentrations exceeding the Water Quality Standard at most of the locations.

The crops survey conducted in 2006 and 2007 show that Pb concentration of wheat exceeded the standard value of Macedonia for 36% of 2006 samples and 22% of 2007 samples. It seems that yearly variations of Pb concentration in wheat exist, suggesting that long term monitoring is necessary to understand the Pb concentrations of wheat in the area.

1.2 Risk assessment

Risk assessment was conducted using the results of the P/P survey.

(1) Exposure Risk of Heavy Metals in Soil Characterised by Land-use

The results of the distribution of the exposure risk by heavy metals in soil show that 400m grids of Level 5, which has risk of 1,000 to 10,000 times more than the risk calculated from 10% of TDI (Torerable Daily Intake) Value as an end-point, occur in limited areas near the Processing Plant and the Tailings Dam No.1. The 400m grids of Level 4, which have the risk of 100 to 1,000 times more than the risk calculated from TDI Value, occur surrounding the tailings dam and along the Kiselica, Koritnica and Zletovska Rivers. The 400m grids of Level 3, which have the risk of 10 to 100 times more than the risk calculated from TDI Value, widely occur in the P/P area.

(2) Total Exposure Risk of Heavy Metals in Soil and Drinking Groundwater

Total exposure risk levels of soil and drinking groundwater in the P/P area consist of four exposure risk levels, ranging from Level 5 to Level 2. The exposure risk of heavy metals in the drinking water is classified as Level 4, and the grids of Level 4 are distributed widely in the west and southeast parts of the P/P area, where groundwater is used for drinking.

(3) Agricultural Risk Assessment of Crops in the P/P

In this study, “agriculture risk” was defined as “the risks of agricultural products by heavy metals” and the agricultural risk used in the report means “the risks of crops (wheat, rice and corn) production by heavy metals”.

The agricultural risk of crops was assessed using the standard value of heavy metals in crops of Macedonia. No clear correlation between Exposure Risk Level of Pb in soil and wheat exceeding the Pb Standard Value (0.2mg/kg) is recognised, The contaminated wheat exceeding the standard value of Pb content is widely scattered in the area, thus the agricultural risk in the area is relatively high. However, the agricultural risk cannot be clearly divided into agricultural high risk and low risk zones in the area due to the limitation of present survey.. As the difference between results of crop analysis in 2006 and 2007 demonstrates annual variation of Pb concentration probably caused by climate conditions and etc.,, it is necessary to continuously monitor the quality of crops for clarifying the agricultural risk in the area.

The purpose of the Pilot project (P/P) was to understand the situation of soil contamination of the P/P area and to implement capacity development for management of soil contamination to governmental institutions and local organisations.

2. Recommendations (Actions)

2.1 Urgent Counter-measures

In the P/P area, the following counter-measure should be taken urgently.

(1) Water from most of the wells/springs of villages in the P/P area has high concentrations of arsenic (As), cobalt (Co), nickel (Ni) and lead (Pb), exceeding the Standard of Drinking Water according to the results of preliminary study using AAS. It is a serious health problem that the water is used for drinking by local residents in half of villages of the P/P area. It is necessary to conduct chemical analysis of the well/springs water at the accredited laboratory (MoH) to confirm the situation of water quality. If the water is confirmed to be contaminated, the counter-measure should be taken immediately to prevent the local residents to use water for drinking and other sources of water supply must be prepared. For taking actions for this problem, it is necessary, at appropriate time, to disclose the actual situation through a proper way of risk communication to the local residents for sharing information and raising awareness and discussing immediate counter-measures.

(2) Finding the scattered distribution of the wheat with high Pb concentration exceeding the standard over the P/P area suggests relatively high agricultural risk and cultivation of wheat must be carefully considered in the P/P area. The yearly variation of heavy metals in wheat found during the P/P suggest that continuous monitoring of wheat with increasing number of samples is necessary to confirm this. After monitoring, proper actions such as changing agricultural product from wheat to something else should be considered.

(3) The tailings dams of TD-I and TD-II are classified as Exposure Risk Level 5. Because they are located close to the residential area and the risk to human health is high, an urgent counter-measure for reducing high risk is necessary. As an urgent counter-measure, either removing tailing material or covering the surface of tailings dam and constructing retaining walls on the west side of the tailings dam should be considered immediately.

2.2 Recommendations

Additional recommendations are given below.

(1) Recommendation on Soil Contamination Surveys

a. It is recommended to include groundwater survey in parallel to soil contamination survey, when planning soil contamination survey. Particularly, for the area where groundwater contamination is anticipated from topographic and hydrological features and wells are used for drinking water, soil/groundwater survey should be conducted promptly.

b. Crops surveys should be included in soil contamination surveys of the agriculture area that have potential of heavy metal contamination.

c. The "Hot Spots" , most of which are related to mining activities, are generally characterised by large-scale potential of soil contamination and are likely to significantly affect human health by harmful substances of heavy metals. Hence, the Hot Spot Survey of soil contamination should be implemented as soon as possible.

(2) Recommendation on Counter-measures

The following remedial counter-measures are proposed in the P/P area for the mitigation of the risk of heavy metal contamination.

- **Priority No.1 –** Tailings dam I and II (proposed as the urgent counter-measures)
- **Priority No. 2 -** Tailings dams TD-IV and TD-V: covering by uncontaminated soil with re-vegetation/re-forestation, retaining walls along the foot of the dike and ditches/culverts for collecting seepage water from the tailings, and water treatment, protection of dust-blowing.
- **Priority No. 3 -** Middle stream of the Zletovska River: removing tailings, tailings should be returned to the new tailings dam.
- **Priority No. 4 -** Lower stream of the Koritnica River: sand controlled dam to stop the rock fragment and gravels with high heavy metal concentrations, install culverts and water treatment.
- **Priority No. 5 -** Lower stream of the Kiselica River: removing tailings; tailings should be returned to the new tailings dam.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrometry
AIST	National Institute of Advanced Industrial Science and Technology
A/P	Action Plan
CA	Capacity Assessment
CARDS	Community Assistance for Reconstruction, Development and Stabilisation
CD	Capacity Development
C/P	Counterparts
CVAAS	Cold-vapour Atomic absorption Spectrometry
DF/R	Draft Final Report
EAR	European Agency for Reconstruction
EC	Electric Conductivity
EDA	Exploration Data Analysis
EEA	European Environment Agency
EEC	European Economic Community
EIA	Environmental Impact Assessment
EIONET	European Environmental Information and Observation Network
EU	European Union
F/R	Final Report
GIS	Geographic Information System
GPS	Global Positioning System
HM	Heavy Metals
HSZ	Public Enterprise Hydro-System Zletovica
ICP	Inductively Coupled Plasma (Emission Spectrophotometer)
IC/R	Inception Report
ISO	International Organization for Standardisation
ISPA	Instruments for Structural Policies Pre-Accessions
IT/R	Interim Report
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
MAC	Maximum Allowable Concentration
MAFWE	Ministry of Agriculture, Forestry and Water Economy
MEIC	Macedonian Environmental Information Centre (MEPP)
MEPP	Ministry of Environment and Physical Planning
MoE	Ministry of Economy
MoH	Ministry of Health
MoLG	Ministry of Local Self-Government
M/P	Master Plan
OJT	On-the-job Training

NEAP-1	1st National Environmental Action Plan
NEAP-2	2nd National Environmental Action Plan
P/P	Pilot Project
RM	Republic of Macedonia
SAPROF	Special Assistance for Project Formulation
SCM	Soil Contamination Management
SEA	Secretariat for European Affairs (Macedonia)
SGV	Soil Guideline Value
SoE	State of the Environment Report
SPM	Suspended Particulate Matter
SSO	State Statistical Office
SW	Scope of Works
TAC	Technical Advisory Council
TD	Tailings Dam
TDI	Tolerable Daily Intake
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
WHO	World Health Organisation
WG	Working Group
WG-AP	Working Group on Action Plan
WG-MP	Working Group on Master Plan
WG-SCM	Working Group on Soil Contamination Management

<u>Heavy Metals</u>

As	Arsenic
Cd	Cadmium
Co	Cobalt
Cr	Chrome
Cu	Copper
Hg	Mercury
Mn	Manganese
Ni	Nickel
Pb	Lead
Zn	Zinc

CHAPTER 1 INTRODUCTION

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1.1 Purpose of the Action Plan

The Action Plan (A/P) for the Pilot Project (P/P) area is one of the results of the "Study on capacity development for soil contamination management related to mining in the Republic of Macedonia", and the A/P was specifically developed concerning the land use of the soil contaminated area.

The purpose of the Action Plan (A/P) is to implement appropriate remedial measures against the soil contamination in the area, based on the results of the P/P survey, and to recommend suitable land use in the area for mitigating the risks of harmful heavy metals related to the mining.

1.2 Objective Area of the Action Plan

The objective area of the A/P is the area of the 400m grid soil survey of the P/P covering 201.5 km^2, which is located in the Zletovica Basin in Probistip (Figure 1.1).

1.3 Content of the Action Plan

The content of the A/P mainly consists of 1) review of the P/P survey, 2) risk assessment of heavy metals, 3) remedial counter measures for soil contamination, and 4) implementation of the plan, which is described in detail as below.

(1) Review of the P/P survey
- Results of the General and Detailed surveys.
- Integrated analyses of the soil and water contamination by harmful heavy metals.
    - High concentration zones of heavy metals in the P/P area.
    - Soil and groundwater contamination mechanism in the P/P area.

(2) Risk assessment of heavy metals in the P/P area
- Method of risk assessment analysis for the P/P.
- Results of risk assessment in the P/P area.
- Specification of soil contaminated area.

(3) Remedial counter measures for soil contamination in the P/P area
- Remedial examples of mine pollution and soil contamination in the P/P area.
- Selection of suitable remediation method in the P/P area.
- Evaluation of risk after implementation of measures in the P/P area.
- Cost benefit analysis.

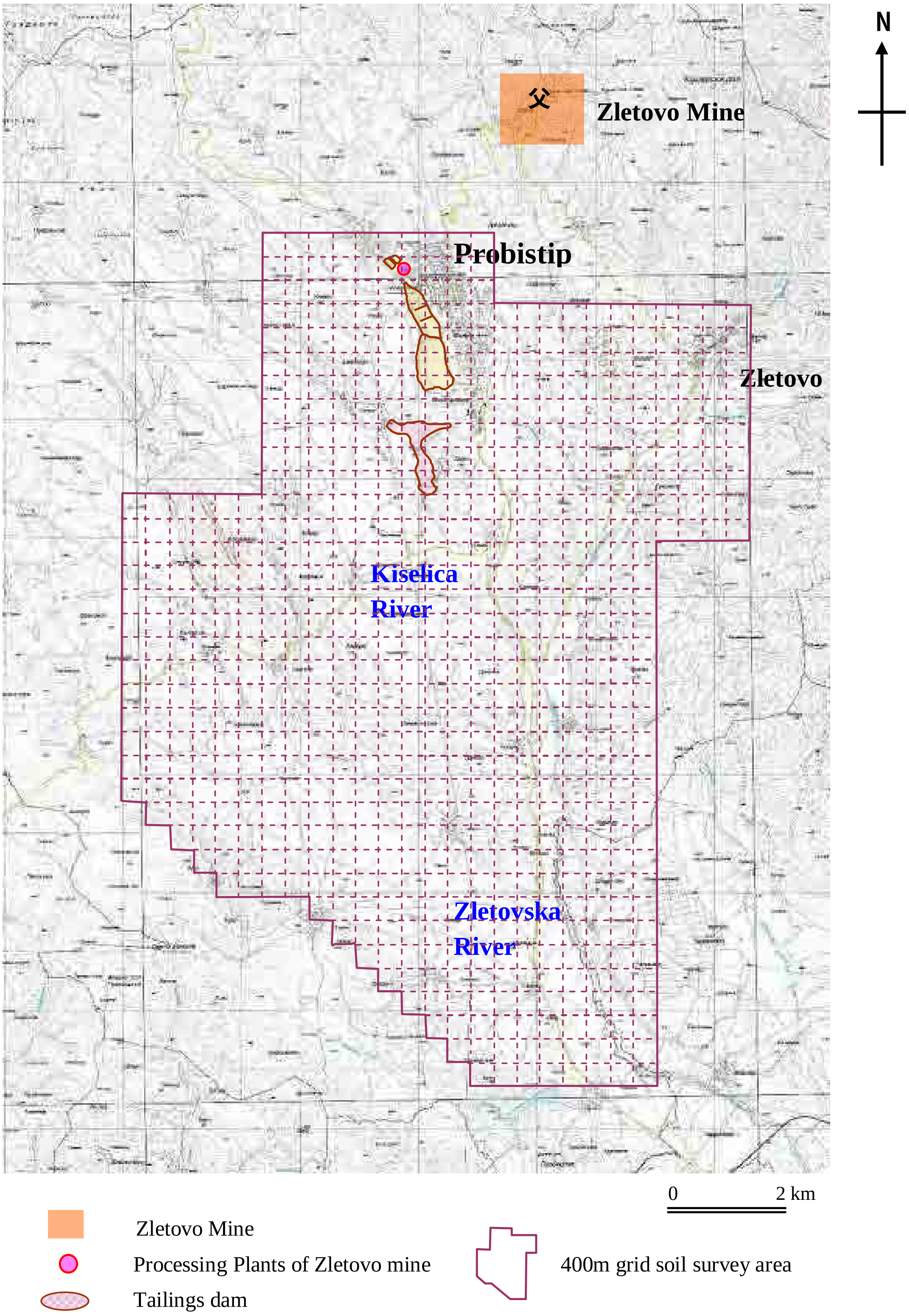


Figure 1.1 Objective Area of the Action Plan and the Zletovo Mine

(4) Implementation of the plan
- Responsibility of remediation of soil contamination in the P/P area.
- Organisation system for implementation of remediation works.
- Schedule of implementation of remediation works in the P/P area.

1.4 Work Flow of the Action Plan

The work flow of the plan is shown in Figure 1.2.

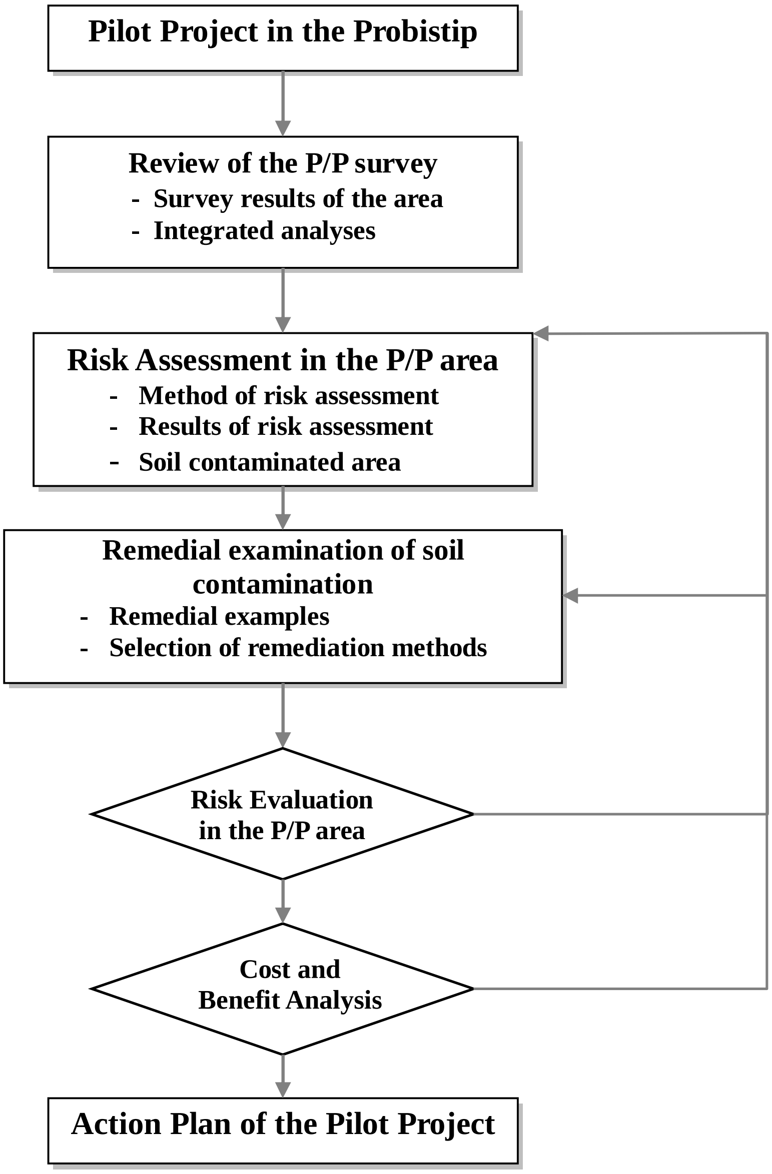


Figure 1.2 Work Flow of the Action Plan of the Pilot Project

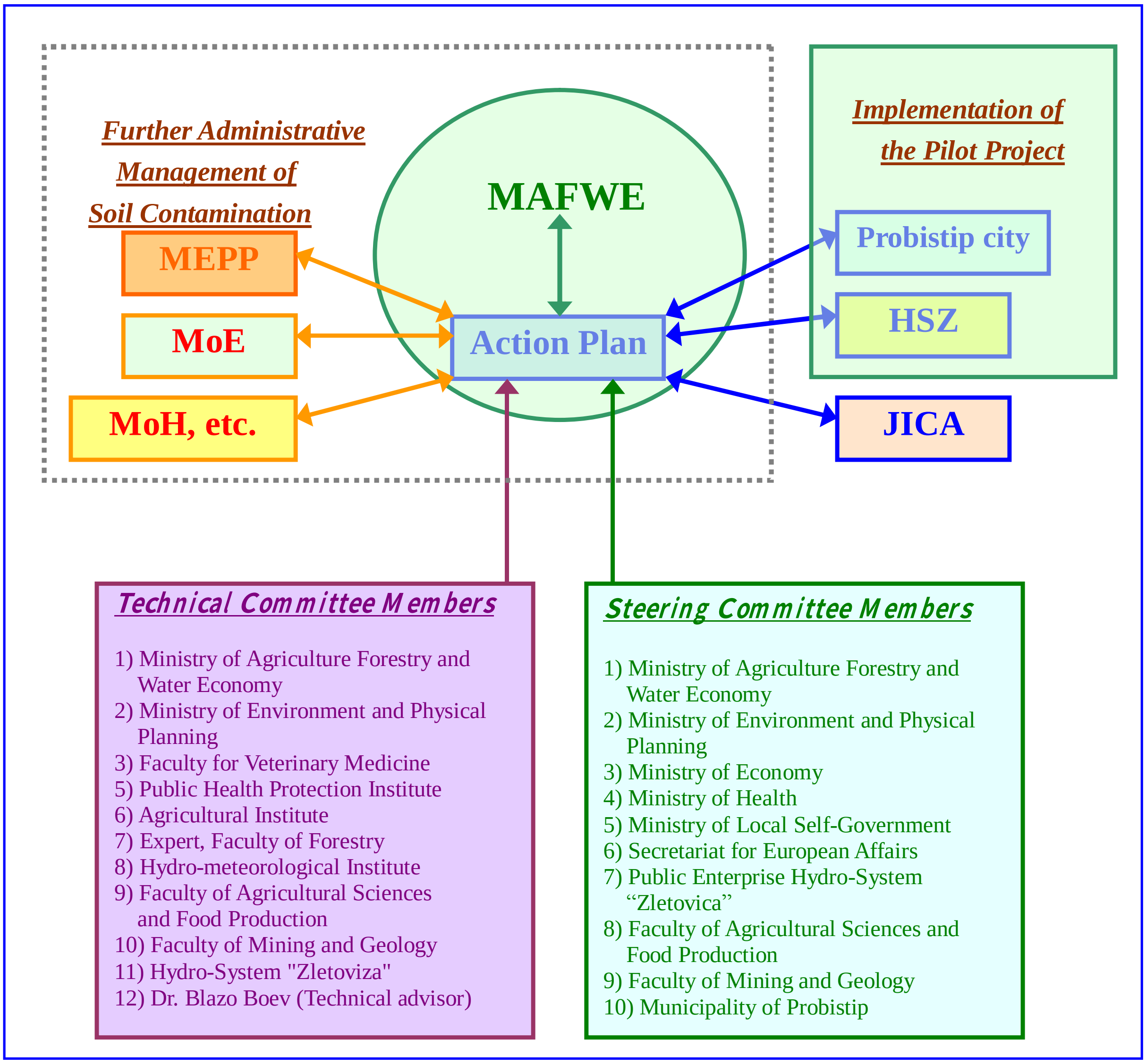
1.5 Study Organisation of the Plan

Since the A/P is basically to remediate the soil contamination in the P/P area of Probistip, the plan should be developed by not only the JICA Study Team and Ministry of Agriculture, Forestry and Water Economy (MAFWE) as main counterpart but also other relevant organisations to the soil contamination management and stakeholders, including the Ministry of Environment and Physical Planning (MEPP), Hydro-System Zletovica (HSZ) and Probistip City.

The Steering and Technical Committees supervise and follow technically the Study, respectively. The study organization is shown in Figure 1.3.

The A/P was mainly provided and discussed by the Working Group for the A/P, consisting of counterparts of MAFWE, MEPP, HSZ, Probistip City and JICA Study Team. Members of the Working Group are shown as below.

(Name of Members)	(Position)	(Organisation)
1. Mr. Vanco Dimitriev	: Director	: MAFWE
2. Mr. Aleksandar Sapundzievski	: Head of department	: MAFWE
3. Mr. Blagoja Stefanovski	: Head of unit	: MAFWE
4. Ms. Vesna Kusakatova	: Associate	: MAFWE
5. Mr. Donco Markov	: Head of section	: MAFWE
6. Mr. Miroslav Nusevski	: Advisor	: HSZ
7. Ms. Ana Maznevska	: State council	: MEPP
8. Mr. Dusco Jovanovski	: Mayor	: Probistip City



MAFWE : Ministry of Agriculture Forestry and Water Economy
MEPP : Ministry of Environment and Physical Planning
MoE : Ministry of Economy
MoH : Ministry of Health
HSZ : Public Enterprise Hydro-System "Zletovica"
JICA : Japan International Cooperation Agency and JICA Study Team

Figure 1.3 Study Organisation of the Action Plan

CHAPTER 2 SURVEY RESULTS OF THE PILOT PROJECT

CHAPTER 2 SURVEY RESULTS OF THE PILOT PROJECT

2.1 Objectives of the Pilot Project

The purpose of the Pilot Project (P/P) was to understand the situation of soil contamination of the P/P area and, at the same time, through on-job-training (OJT), to implement capacity development for management of soil contamination to governmental institution and local organizations. The results of the P/P study can be used as a case study for understanding the situation of the other similar mine areas in Macedonia.

2. 2 Content of the Pilot Project

The General Survey, Detailed Survey and Additional Survey, as shown in Table 2.1, were carried out in the P/P area. The study items and work achievements of the P/P are given below and in Table 2.1.

- Seminar concerning the P/P
- General Survey
  - Stage-1 soil survey: 400m grid soil survey
  - Stage-2 soil survey: 200m grid soil survey
  - River bottom sediments survey
  - Surface water survey
  - Drilling wells and monitoring of groundwater
  - Drilling survey in tailings dams
- Progress Report
- Second Workshop
- Detailed Survey
  - Stage-3 (1) soil survey: 100m grid soil survey
  - Stage-3 (2) soil survey: 50m grid soil survey
  - Crops Survey
  - 5m deep drilling survey
- Distribution map of heavy metal concentration
- GIS data construction work
- Compilation of survey results
- **Action Plan**
- Interim Report
- Third Workshop
- Additional Survey
  - Groundwater and surface water survey
  - Additional crop and soil survey

Table 2.1 Works Completed for the Pilot Project

Stage of Survey		Survey Item		Approximate Amount			Unit	Remarks
				Number of Grid		Total		
				Content Analysis	Elution Analysis *1			
Phase 1		Tailings (Tailings dam) and others		20	20	40	piece	Tailings, mineralized zone, etc.
		Background survey		20	20	40	piece	Outside of P/P area：24 components
Phase 2	General Survey	Surface soil	400m grid	679	141	820	piece	Stage-1 Survey：10 components *2
			200m grid	536	54	590	piece	Stage-2 Survey（20% of Stage-1 area)
		Sediments		-	-	6	piece	Kiselica Rivers, Zletovska River
		Surface water		-	-	6	piece	Kiselica River, Zletovska River
		Groundwater	Drilling	-	-	12	hole	Kiselica River, Zletovska River: Total 135m
			Chemical analysis	-	-	72	piece	Chemical analysis：6 months × 12
		Tailings dam	Drilling	-	-	2	hole	Old TD: 40m, New TD: 28m *3
			Chemical analysis	36	36	72	piece	Old and New TDs
		Ground water		2	-	2	piece	Old and New TDs
	Detailed Survey	Surface soil	50m grid	800	80	880	piece	Stage-3 Survey
			100m grid	288	29	317	piece	Stage-3 Survey
		Deeper soil	Drilling	-	-	50	hole	5m deep/hole =240.5m
			Soil and sediments	400	40	440	piece	8 samples/hole
		Crops		-	-	104	piece	Wheat (84), Corn (16), Rice (4)
Phase 3	Additional Survey	Groundwater and surface water	Well water	-	-	95	piece	95 water wells
			River water	-	-	31	piece	36 of rivers and water springs
		Crop Survey *4	Wheat Crop	-	-	(32)	piece	32 wheat samples
			Soil	(32)	(32)	(64)	piece	Same location to wheat samples

*1: Conducted for 10% of Content Analysis samples except for 400m grid soil samples.

*2: Chemical analyses of 10 components were conducted for all the samples.

*3: TD: Tailings dam.

*4: Crop Survey were carried out by the Ministry of Agriculture, Forestry and Water Economy.

The field work of the P/P was carried out from late May 2006 to the middle of July 2007, and the chemical analyses were completed by end of July 2007.

2.3 Flow of the Pilot Project

The P/P was conducted following the flow chart shown in Figure 2.1

Prior to the commencement of the P/P study, a seminar was held on May 31, 2006. The P/P survey consisted of two separate surveys; General survey and Detail survey. The former was conducted between late May to late September 2006 and the latter between early October to late December 2006. The results of P/P survey were analyzed and compiled from the middle of January to the middle of February 2007.

2.3.1 General Survey

The surface soil survey was conducted at four different grids of 400m, 200m, 100m and 50m grids by narrow down method, aiming at understanding of the situation of heavy metals concentration, cause and mechanism of soil contamination in the P/P Area. In the General Survey, 400m grid and 200m grid surveys of surface soil sampling were conducted and, in addition to them, river bottom sediments and surface water were collected from the typical streams of the P/P area. Further, drilling of monitoring wells and drilling of tailings dam were conducted during the General Survey.

(1) Surface Soil Survey: For understanding an outline of the heavy metal concentrations of the whole area of P/P Area, 400m grid sampling was, at first, conducted covering a whole area of the P/P Area. Based on the results of 400m grid soil survey, then, the 200m grid soil survey was conducted in the area of high heavy metal concentrations extracted by the 400m grid survey to narrow down the area of high heavy metal concentration.

(2) Tailings Survey：For understanding the chemical nature of the tailings materials of tailings dam, two drill holes, one each at the Old and the New Tailings Dams, were drilled.

(3) River bottom Sediments Survey: River bottom sediments were collected at 6 locations of the main stream of the Zletovska and Kiselica rivers for understanding the heavy metal concentration of the river bottom sediments.

(4) Surface water Survey: Surface water was collected at 6 locations same as the locations of river bottom sediments, for evaluation of the surface water in the P/P Area.

(5) Groundwater Monitoring: A total of 12 monitoring wells for monitoring groundwater were drilled in the potential area of the soil contamination to understand groundwater contamination. The monitoring of groundwater was conducted once in a month continuously for 6 months starting from August 2006 to January 2007.

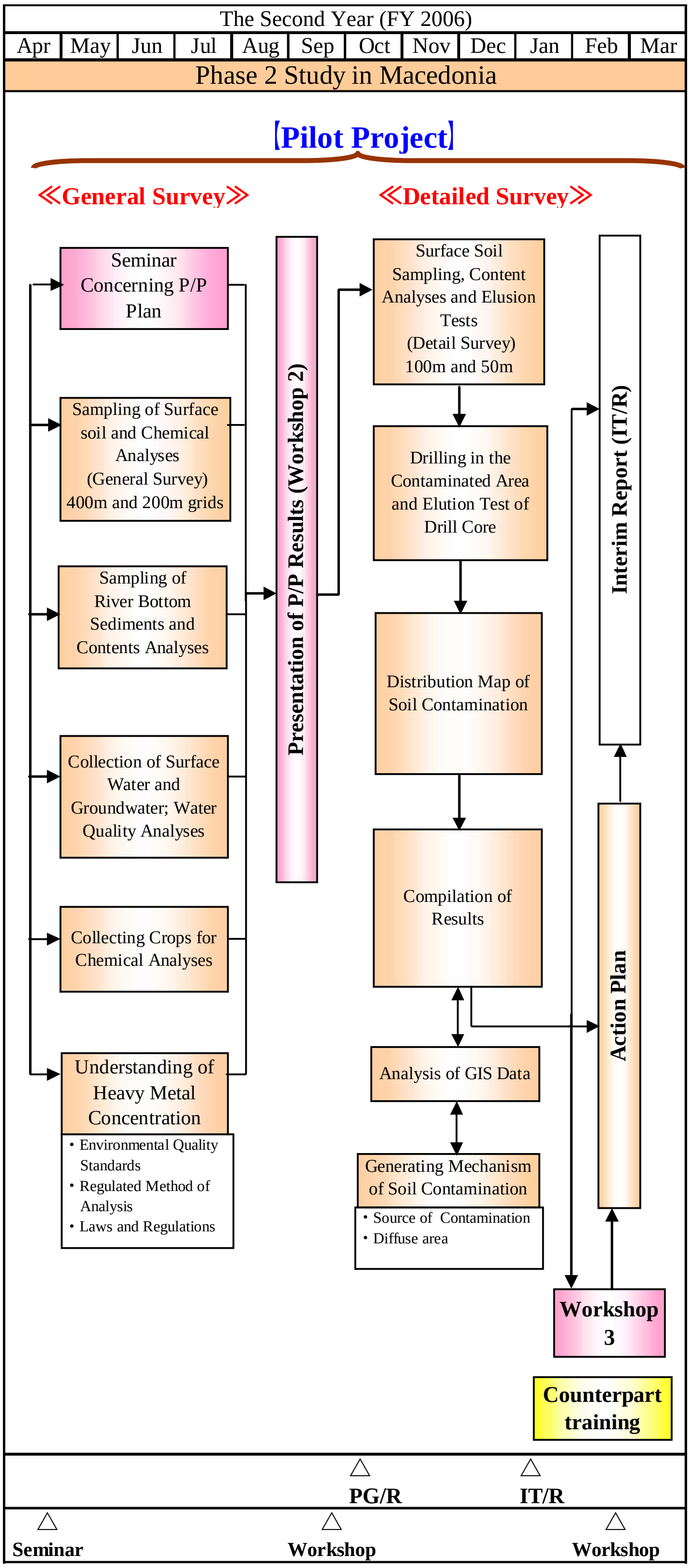


Figure 2.1 Flow Chart of Phase 2 of the Pilot Project

(6) Chemical analysis of Crops: On the basis of the environmental risk assessment for soil contamination by heavy metals related to mining, wheat, corn and rice were collected for chemical analysis.

2.3.2 Detailed Survey

In the Detailed Survey, 100m grid and 50m grid surveys of surface soil sampling were conducted and, in addition to them, the drilling survey of soil was conducted.

(1) Surface Soil Survey: Based on the results of the 400m grid and 200m grid survey, 100m grid survey was conducted mainly over the area of high heavy metal concentration of 400m grid in the highland area, while 50m grid survey was conducted over the area of high heavy metal concentration of 200m grids.
(2) Drilling Survey of Soil: Based on the results of general survey of P/P, the drilling survey of 5m deep was conducted over the area of high heavy metal concentration for the purposes of understanding the vertical profile of heavy metal concentration and defining causes of heavy metal enrichment.

2.3.3 Additional Survey

Based on the results of the Detailed Survey, the Additional Survey was conducted.in Phase 3 (2007).

(1) Additional Groundwater and Surface Water Survey: For further understanding of the heavy metal concentrations of groundwater and surface water in the P/P area, the additional survey of groundwater and surface water covering the whole area of the P/P was conducted.

(2) Crop Survey: Sampling and chemical analysis of 32 pairs of wheat samples and soil samples were conducted to examine yearly variation of Pb in wheat and the relations of Pb concentrations between wheat and soil.

2.3.4 Compilation Work

All the results of surveys of the P/P Area were complied and analyzed for understanding the nature and distribution of high heavy metal concentration in soil, sediments, groundwater and crops, and the mechanism of enrichment of heavy metals in the P/P area was considered.

2.4 Present Situation of the Pilot Project Area

The P/P Area is located in the Zletovica Basin in Probistip, covering the area of 201.5km^2.

2.4.1 Topography

The P/P area is topographically classified into areas of mountain, hill, terrace, flat plain and river plain. The mountainous area, with elevation of 700m to 1,000m, occupies the northern part of the P/P area, showing steep mountainous topography. The hills occur continuously from the mountains, stretching southward. In the area west of the Zletovska River, the hills are distributed being aligned in four parallel lines of the northwest-southeast direction. They show cuesta topography reflecting the distribution of the geological unit. The hills rise approximately 100m higher than the surrounding flat plain. Along the west side of the Zletovska River and southeast part of the area, the hills are partly covered by terrace plains on top.
Three terrace plains of upper, middle and lower plains are observed in the area. The upper terrace plains occur on the top of hills with flat plains of 500m high in the north and flat plains of 400m high in the south. The middle plain with elevation of 470m to 480m only occurs on the east side of the Zletovska River in the northwest of the area. The lower terrace occurs along both sides of Zletovska River, occupying the area of 200m to 1,500m wide. The lower terrace plain is 450m high in the north and 320m high in the south and it is 2m to 4m higher than alluvial river plain.

The alluvial river plain mainly occurs along the Zletovska River and in a small area of its tributaries.

2.4.2 Geology

The P/P area geologically belongs to the Kratovo-Zletovo volcanic area with a wide distribution of Tertiary volcanic rocks to which spatially and paragenetically mineral deposits are associated (Figure 2.2). The volcanic rocks are mainly Miocene and Pliocene of the Tertiary and Pleistocene of the Quaternary in age, and they consist of andesitic to dacitic lavas, dykes and pyroclastic rocks. The pyroclastic rocks are mainly volcanic breccia and tuff, and they are complicatedly distributed with intrusive rock such as porphyrite and lavas.

The Zletovo Mine area, located in the northeastern part of the P/P area, consists of Miocene ignimbrite (dacitic tuff and tuff breccia) and dacitic lava, such as latite, and they are intruded by dyke rocks.

In the other part of the P/P area, northwestern and southern parts, volcano-sedimentary sequences consisting of andesitic to dacitic pyroclatic rocks and sedimentary rocks occur trending in NW-SE direction. The ages of these rocks are Eocene, Miocene, Pliocene and Pleistocene, and they are

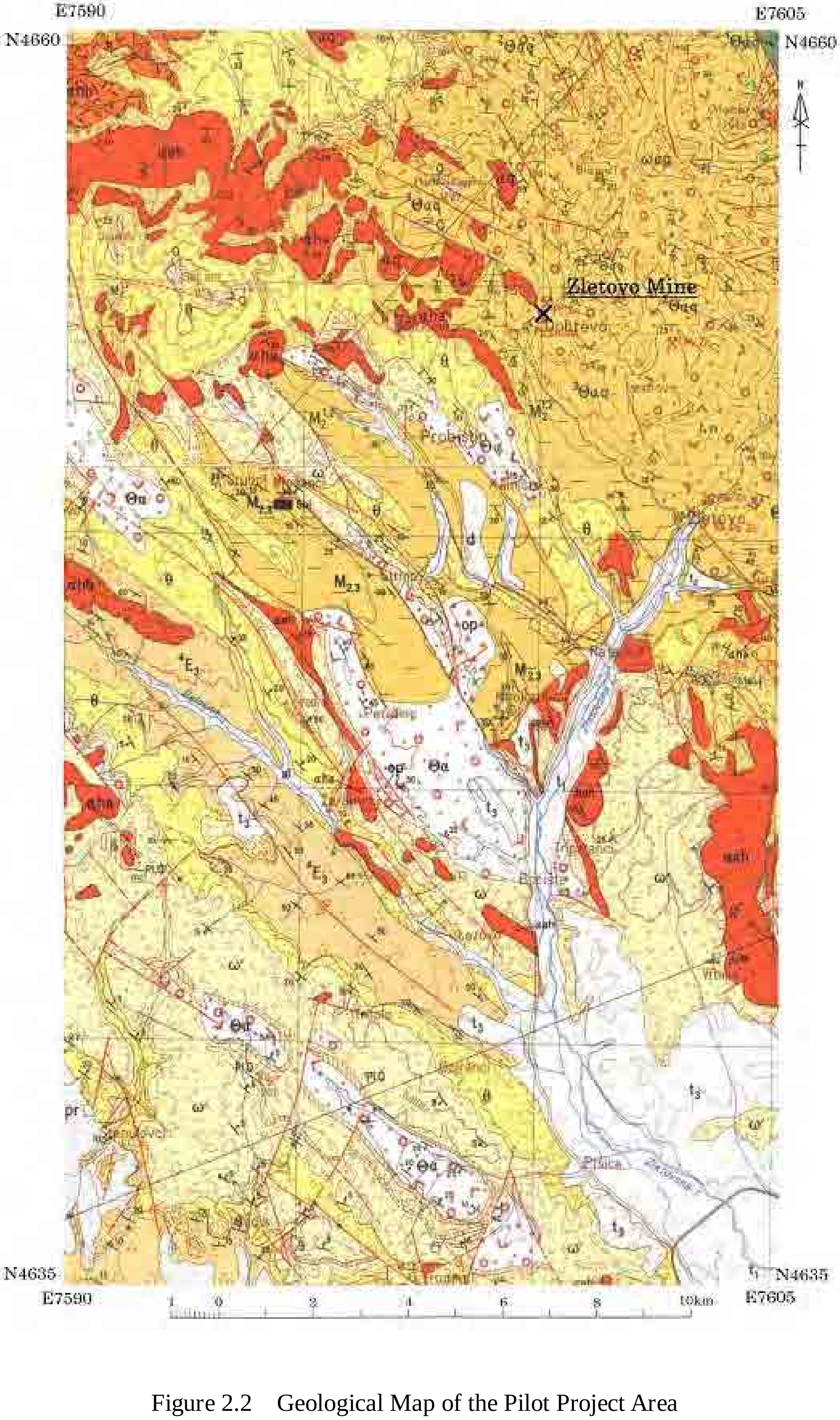


Figure 2.2 Geological Map of the Pilot Project Area

Legend of the Geological Map

Holocene

- Alluvium
- Lower terrace
- Upper terrace
- Diluvium
- Proluvium
- Old river terrace

Pleistocene

- Hydrothermal quartz
- Opal breccia
- Andesite tuff
- Hornblende augite andesite
- Andesite ignimbrite
- Tuffaceous carbonate rock

Pliocene

- Dacitoid
- Augite hornblende biotite andesite
- Andesite breccia
- Hornblende augite biotite andesite
- Andesite tuff

Miocene

- Marl, tuffaceous sand and clay
- Marl, tuffaceous sand and bitominous clay
- Breccia of dacite composition
- Pale greenish gray ignimbrite of dacite composition
- Grayish pink ignimbrite of dacite composition
- Dark gray ignimbrite of dacite composition

Eocene

- Upper zone of flysch, clay, sand and others partly covered by Pliocene andesite lavas. The distribution of NW-SE trending volcano-sedimentary sequences of Tertiary to Quaternary are reflected to the topographic feature, forming NW-SE trending hills in the area.

2.4.3 Hydrology

All the rivers in the P/P area belong to the Zletovska River system, which starts from the north near the Bulgarian border and flows north to south in the eastern part of the P/P area before reaching to Bregalnica River (Figure 2.3). The main rivers in the P/P area, other than the Zletovska River, are Koritnica River, Kiselica River and Belocica River, and all of them flow into the Zletovska River from the west.

The Zletovo Mine is located in the upstream area of Koritnica River and the tailings dam is located along a tributary of Kiserica River. There is no significant river system observed to the east of the Zletovska River. The planned irrigation areas of the Zletovica Basin Water Utilisation Improvement Project are located in the area of the Zletovska, Kiserica and Belocica Rivers.

2.4.4 Land Use and Vegetation

Conifer forest and shrub cover the northern part of the mountainous area of the P/P area (Figure 2.4). The areas between mountain and hills are used for pastures for sheep and cattle.

Vineyard and orchard are mainly found in the area of topographic turning point between mountain-hills and hills-flat plains. In the orchard, mostly apple and pear are grown and partly sour cherry, plum and walnut are observed. The agriculture land is, partly, observed on the hills, but the hills are mainly occupied by pasture land and shrub. Agriculture land, mostly used for cultivation of wheat, occupies part of the hills and flat areas between the hills. Idle farmland, cultivated in the past and planed to be cultivated in the future, is observed in the southwest part of the area.

Rice used to be widely cultivated in the lower terrace area along the Zletovska River, but because of the low market price of rice, the areas were gradually transferred to corn and wheat fields. In some places, partitions of rice fields still remain in the area and different crops are cultivated each year depending on situation.

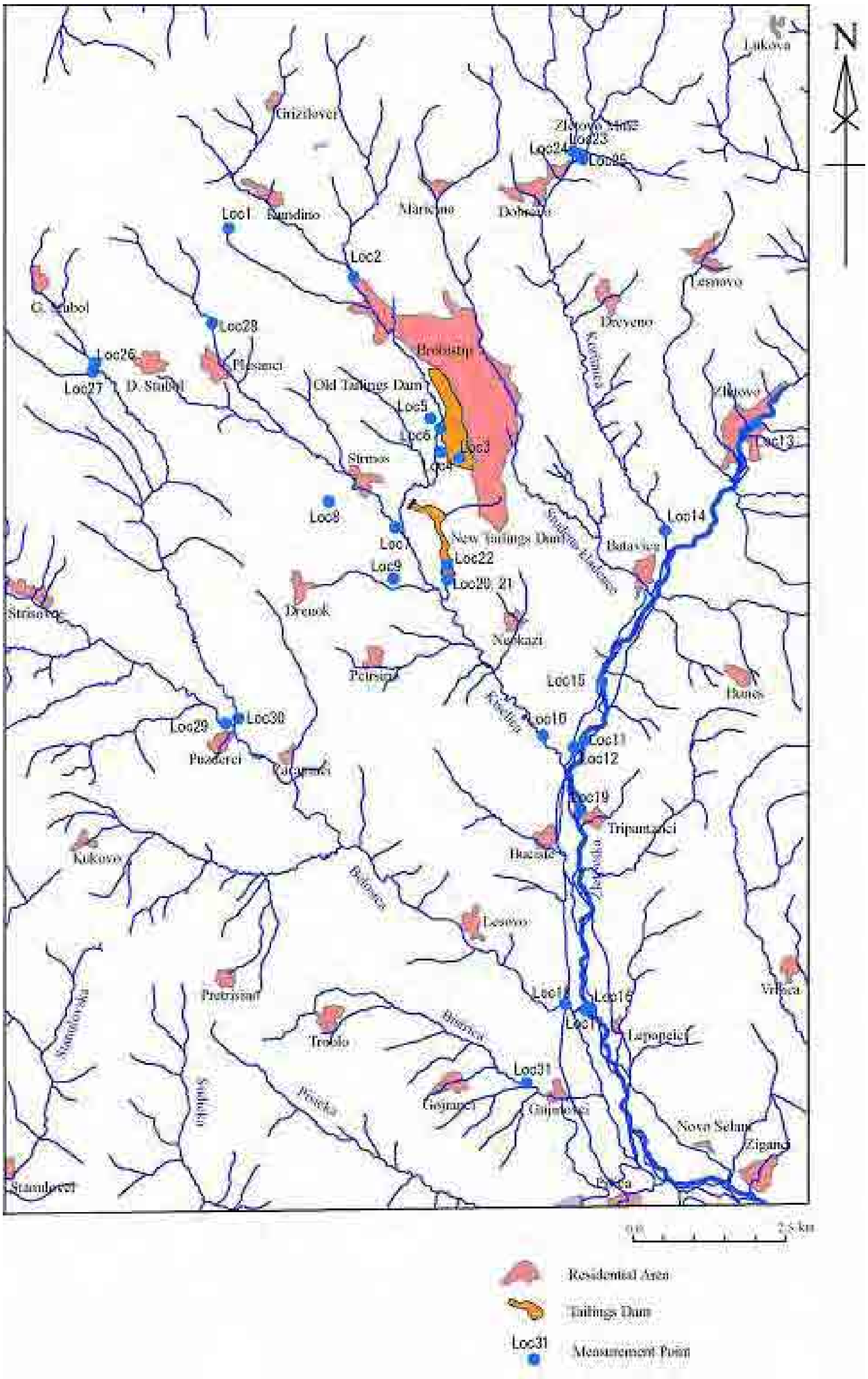


Figure 2.3 Hydrology and Distribution of Residential Areas of the Pilot Project Area

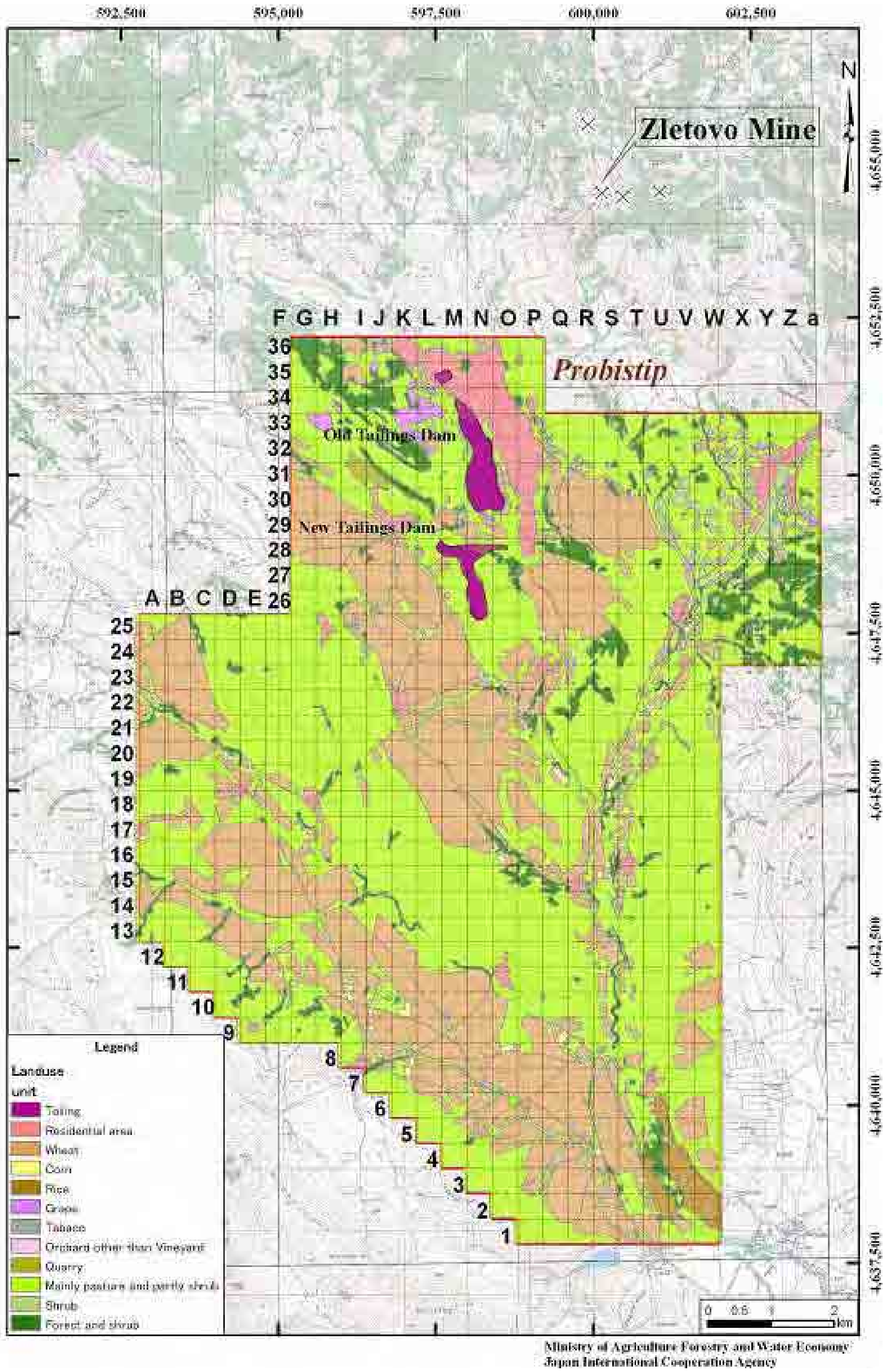


Figure 2.4 Land Use and Distribution of Crops in the Pilot Project Area

2.4.5 Agriculture in Probistip

Agricultural production is currently very important to the local economy in Probistip. The climate in Probistip is suitable for arable crops, in particular wheat. Table 2.2 shows the agricultural production in Probistip Municipality in 2005. As shown in the table, the main agriculture products of Probistip are wheat and barley in addition to some vegetables and fruits.

Table 2.2 Agricultural Production in Probistip in 2005

Type of Agriculture	Surface Area (ha)	Production (kg/ha)	Total Production (kg)
Wheat	2,700	3,000	8,100,000
Barley	1,300	2,900	3,770,000
Corn	380	2,000	760,000
Other plants	50	2,500	125,000
Potatoes	80	10,000	800,000
Beans	50	1,000	50,000
Watermelon	40	8,000	320,000
Other gardening cultures	110	-	150,000
Barley	100	1,000	100,000

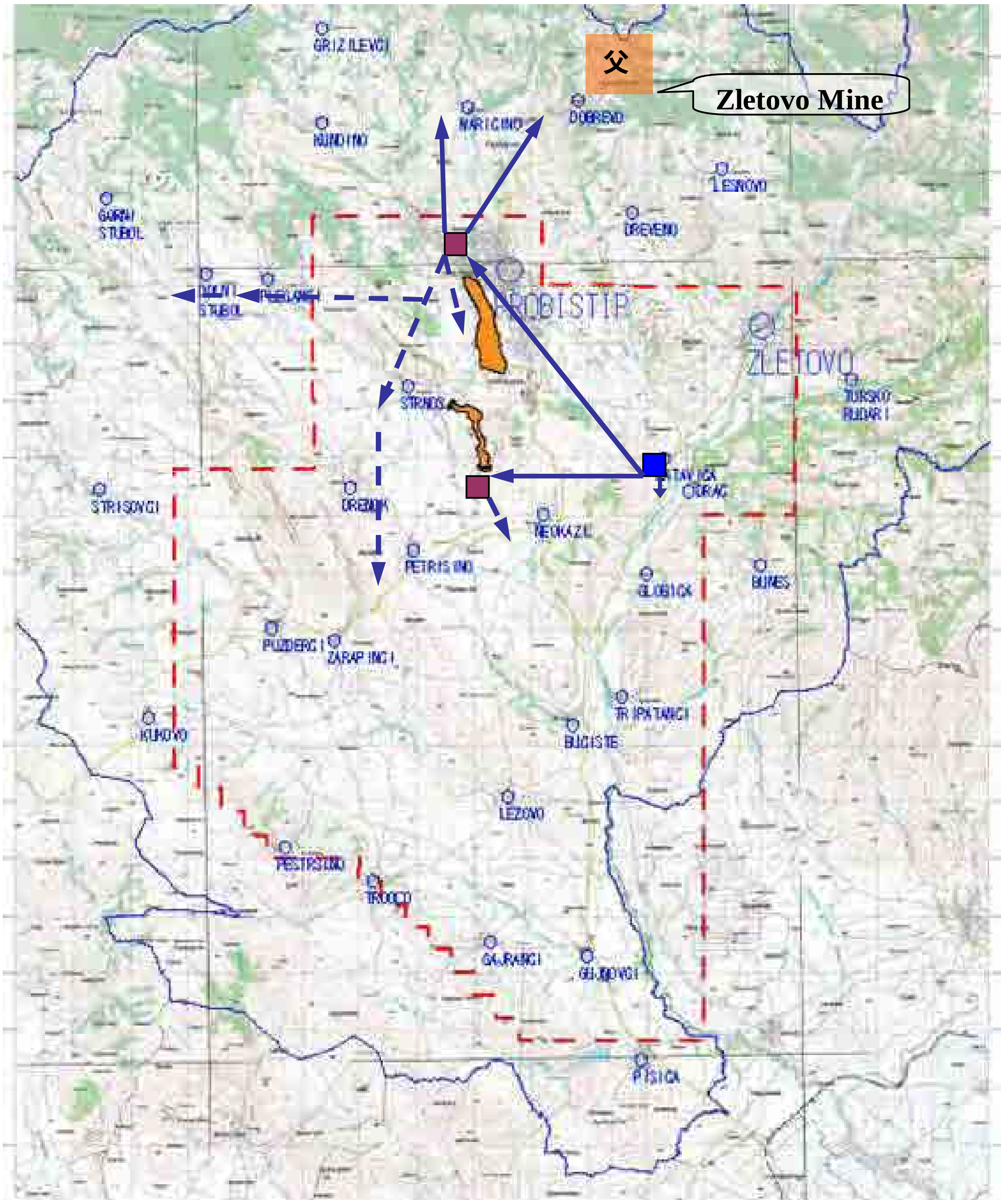
Source: Agro-economical aspects of agriculture in Probistip Municipality (2006).
(Diploma work by the Faculty of Agricultural Science and Food, University of Skopje)

2.4.6 Water Use

The majority of the drinking water supply for people in Probistip and nearby villages is taken from 35 groundwater wells (7m to 9.5m deep) between Ratavica and Drac. From the pumping station in Ratavica, the water is pumped up to a holding tank near Probistip, treated with chlorine, and supplied to Probistip townsite and many surrounding villages (Neokazi, Petrsino, Strmos, Plesenci, Maricino, Dobrevo and Dolni Stubol). Several of these villages are downstream of the tailings dam, but most of their water supply is taken from groundwater at Ratavica - Drac. Figure 2.5 shows the water supply systems.

Several of the households, farms and businesses in Probistip and other villages that are supplied by the Municipal Water Company also have their own private groundwater wells, but these are mainly used for irrigation purposes for vegetables and crops. In the villages that are not supplied by the Municipal Water Company, the community uses water from springs and groundwater wells for drinking water and irrigation. It is estimated that approximately 25% of households in Probistip have their own groundwater wells, although it is reported that a higher proportion of houses have wells in Zletovo and some villages.

The depth of the private groundwater wells varies depending on the groundwater levels, and typically are 5m to 10m deep. For example, in Ratavica, the private wells are 7 to12m deep, but in Tripitanci there is a shared well that has a depth of 4 to 5m.



Pumping Station and holding tank of Probistip Municipal Water Supply Company

Route of pumped water by Probistip Municipal Water Supply Company

Reservoir tank of Probistip Municipal Water Supply Company

Route of water supply by gravity by Probistip Municipal Water Supply Company

Figure 2.5 Locations of Towns and Villages in Probistip Municipality and Water Supply by Probistip Municipal Water Supply Company

2.4.7 Irrigation

Irrigation is a major problem for agricultural activities in the Probistip area and the construction of the multipurpose regional Hydro System "Zletovica" (HSZ) presents positive opportunities to improve the agricultural production in Probistip through improved irrigation.

Apart from the fields near to the Zletovska River, the main irrigation water for crops comes from private groundwater wells, particularly for the large number of small farms and households that grow their own crops and vegetables. In addition at Pisica and surrounding areas in the south of the P/P area, there is some irrigation from the reservoir that was constructed in 1976.

2.4.8 Socio-economic situation

The town of Probistip, including the surrounding villages in an area of rural agricultural land, is an example of the social challenges in Macedonia at present. Probistip Municipality has a population of about 16,200 within about 329km^2. The municipal boundary includes the town of Zletovo, as well as the main town of Probistip. The population of Probistip town is about 10,800.

The growth of Probistip increased with the development of the lead/zinc mines (Zletovo) from the 1950s, as well as a large battery factory. Infrastructure development and population expansion gradually transformed Probistip into a town with one of the strongest local economies in Macedonia.

However, from the late 1970s the Municipality has suffered from economic crisis and lack of demand for the mining products, and the challenges have continued through the period when Macedonia has developed as an independent country. The battery factory is currently running at a very low capacity and many small enterprises that depended on the mining and battery industry have been affected.

There are many small villages in the area, but most have a lack of modern infrastructure in terms of water supply, electricity, etc. Agriculture has recently been the most important sector for Probistip Municipality. Crops such as wheat, corn, rice, numerous types of fruit, and tobacco, are grown, and there is some livestock.

Although the socio-economic situation in Probistip Municipality is difficult, the re-opening of the Zletovo mine is starting to have a positive social impact on the area of Probistip, with increased employment and related service needs. The construction of the multi-purpose regional hydro system (Zletovica), and the P/P on soil contamination are positive opportunities to greatly improve the social, economic and environmental situation in Probistip.

2.4.9 Tailings Dams and Spill Incidents

(1) The Zletovo Mine

The Zletovo Mine is located in the mountainous area, 5km northwest of town of Zletovo and 3.5km northeast of town of Probistip. The main production of the mine is lead and zinc by underground mining, and mining facilities mainly consist of mine adits and mine office in the mining site, tunnel between the mine site and processing plant (at Probistip) for transportation of crude ore, main office and processing plant in Probistip, and tailings dams located in the south of Probistip.

(2) History of the Zletovo Mine

The main events and production of the Zletovo Mine are compiled in Table 2.3. The first mining activities in the Zletovo (Probistip) area were registered even before Roman age. Actual mining evidence and relicts in the area also existed after the Roman age.

In 1926, the Pasic family from Serbia had been owner of the Kratovo-Zletovo Mines, having the concession of exploitation of the mines. In 1928, they sold it to an English company, Selection Trust Limited, and in 1938, all the concession was transferred to the newly established company, Zletovo Mine Limited. The company had commenced systematic surveying from 1929 to 1934 and had constructed the facilities for exploitation and processing of the ore from 1935 to 1941 in Probistip. Actual exploitation of the mine had started after occupation by the Germans in 1941. According to some unofficial data, the production quantity until September 1944 was 70,000t of lead from 130,000t of crude ore.

After the Second World War, normal production was resumed in 1945. At that time, the population of Probistip was 500 people, and then in 1952, Probistip became a municipality.

The annual production of ore in 1945 was 20,205t, and in 1949 it reached 203,235t. In the next five years, the annual production maintained the same level as in 1949, and the annual production had increased 2% in each year between 1958 and 1968.

From the beginning of production in 1945 until 1988, a total of 12,623,859t of crude ore has been excavated and a total concentrate of 968,276t of lead and 338,236t of zinc had been produced, according to the detailed research in 1988.

In 1971 and 1972, new facilities and equipment, including a tunnel for transportation of crude ore from the mine site to the processing plant instead of the cable transportation system, were installed in the production process, which resulted with increase of annual production from 280,000t (1968) to 470,000t (1978) in the following years.

Table 2.3 History of the Zletovo Mine

Year	History
Roman age	Mining evidence and relicts in the area: Caves, wastes, etc.
1926	Pasic family (Serbian) had been owner of the Kratovo-Zletovo Mines.
1928	English mining company bought Zletovo Mine.
1929 - 1934	Enforcement of exploration in the mine area.
1938	Newly established company was established for operating mining.
1935 - 1941	Mining facilities for exploitation and processing were constructed. In Probistip
1941 - 1944	Mine was occupied by the Germans and produced 70,000t of Pb
1945 - 1952	Mining operation was restarted in 1945. Annual production: 20,205t in 1949, and 203,235t in 1952 as crude ore.
1953 - 1968	Annual production: 200,000t to 280,000t as crude ore.
1971 - 1972	New facilities and equipments were installed.
1973 - 1976	Spill accidents of tailings in Old Tailings Dam: (TD-IV) 290,000m^3 (150,000t).
1976 - 1986	Restoration of broken dams and re-piling by tailings at Dam-IV and V.
1987 - 2003	New Tailings Dam started to pile from 1987.
2003	Mine was closed.
2006 -	INDO Minerals and Metals has started to re-operate Zletovo Mine.

During the 1990s the economy of Macedonia also significantly declined by the collapse of former Yugoslavian market and local conflicts and further, after 2000, Macedonian's lead-zinc mining and industry faced contamination-related closures, raw material shortages and financial difficulties. In March 2003, the Government decided to close the Zletovo smelter/refinery and chemicals facilities.

In December 2006, over one year after buying Zletovo Mine, INDO Minerals and Metals has started to re-operate the mine and processing plants.

(3) Tailing Dams of the Zletovo Mine

a. Oldest Tailings Dam (TD-I) between 1928 and 1944

It was necessary to construct tailings dam by piling the tailings that occurred by processing the concentrate from crude ore. The tailings that occurred by the operation between 1928 and 1944 were piled at the small tailings dam (TD-I) located at the northwestern side of the processing plant as shown in Figure 2.6.

TD-I dam was constructed by the inter piling method of flat type (Table 2.4 and Figure 2.7). The volume of the oldest tailings is approximately 150,000m^3.

At present, the Oldest Tailings Dams are used as two soccer pitches, consisting of main pitch and sub-pitch. The surface of soccer pitches are covered by 1.10m thick of uncontaminated soil and grass, but a part of surface in and around the TD-I has been confirmed to have a high concentration of heavy metals, and tailings on the side slope of the tailings dam can be directly observed, exposed by local erosion with seepage water. Old tailings still contain very high concentrations of heavy metals including Pb, Zn, Cd, Cu and Mn.

b. Old Tailings Dams (TD-II, III, and IV) between 1945 and 1970s

After the Second World War, the mining operation had re-started from 1945. Although the mining production in 1945 was only 20,205t (as crude ore), the annual production had rapidly increased, and had reached 278,950t in 1968.

The tailing dams (TD-II and III) were newly constructed at the left-bank side along the Kiselica River, located adjacent to the south western part of Probistip town site as shown in Figure 2.6.

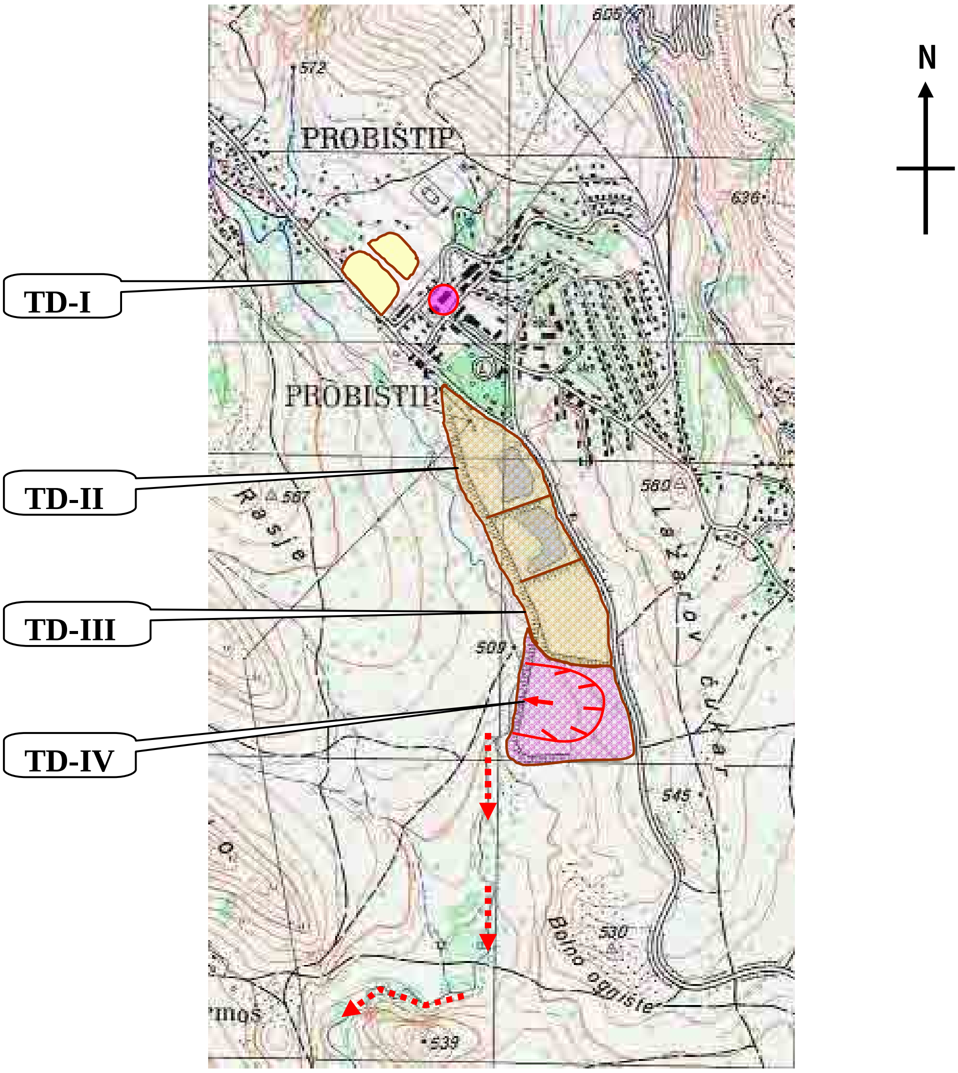
TD-II and TD-III dams were constructed by inter piling method of flat type. The volume of the tailings in TD-II and III is approximately 100,000m^3 and 750,000m^3, respectively (Table 2.4).

At present, TD-II and TD-III areas are covered by soil and surplus soils of construction in thickness of 2 to 2.5m conducted by Probistip City and MAFWE. In particular, TD-II area is reused by electric sub-station, garage, etc., and TD-III area is also re-planted by trees managed by Probistip City and MAFWE. However, a part of surface soil in TD-II and TD-III areas are confirmed to have high concentration of heavy metals due to affection from the bear surface of tailings dams such as TD-IV and TD-V.

After renovation (1971 to 1972) of mining facilities and equipment for increasing production, the tailings also were increased and newly piled at the south part of TD-IV as shown in Figure 2.6.

The tailings were piled in the shape like a trapezium, being 300m to 400m wide, 300m to 400m long and about 22m high in maximum, as shown in Figure 2.8. TD-IV dam was also constructed by inter piling method of flat type. The volume of the tailings in TD-VI is thought to be approximately 900,000m^3 (Table 2.4).

In 1976, the collapse of the tailings dam occurred in TD-IV as shown in Figures 2.6 and 2.8, and tailings of about 290,000m^3 were spilled away to the lower stream areas of Kiselica and Zletovska Rivers. However, the tailings spill-out was re-calculated to about 290,000m^3 according the "Report on Zletovo Tailings Dam Spill Accident" (Zletovo Mine, 1979).



(Taken from Topographic map produced by Cardinal Authority, 1971)

0 0.5 km

Tailings dam (TD-I) constructed between 1928 and 1944

Tailings dam (TD-II & III) constructed between 1945 and 1970s

Tailings dam (TD-IV) constructed between 1970 (?) and 1976

Collapse and spill of tailings

Processing plant

Figure 2.6 Construction of Tailings Dams between 1928 and 1973

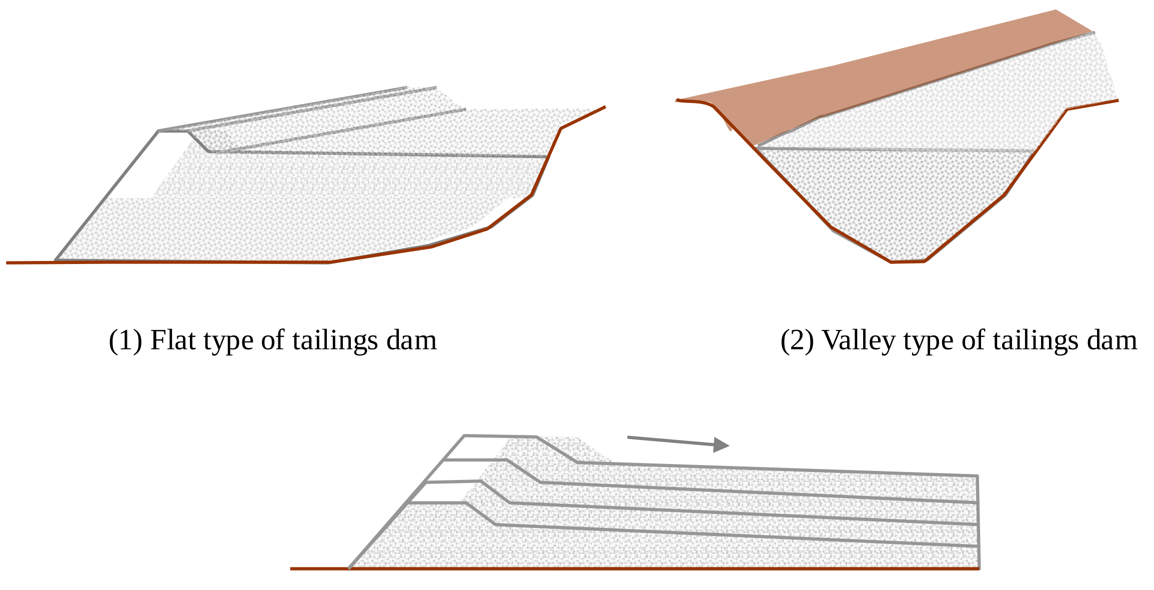
Table 2.4 Tailings Dams in Probistip

Tailings Dam (TD)	Location	Type	Volume (m^3)	Remarks
TD-I	Northwest of processing plant	Flat*1/IP*2	150,000	Used as succor pitches
TD-II	Left river side along Kiselica River	Flat/IP	100,000	
TD-III	Left river side along Kiselica River	Flat/IP	750,000	
TD-IV	Left river side along Kiselica River	Flat/IP	900,000	Collapsed
TD-V	Left river side along Kiselica River	Flat/IP	1,100,000	
New TD	Lower part of Kiselica River	Valley*3/IP	-	Re-started to operate

*1: Flat type tailings dam: Retaining dikes of tailing dam has 2 ~ 4 faces as shown in Figure 2.7 (1).

*2: Internal piling method of tailings: as shown in Figure 2.7 (3).

*3: Valley type tailings dam: Constructing in the valley as shown in Figure 2.7..



(1) Flat type of tailings dam

(2) Valley type of tailings dam

(3) Internal piling method of tailings

Figure 2.7 Piling Type of Tailings Dams

Although the cause of collapse of TD-IV was not clarified at that time, the main possible causes are assumed to be 1) the retaining dike of TD-IV was too weak against unstable tailings materials due to loose piling of materials and/or poor design of dams, 2) pore water pressure in the dam had increased due to inadequate drainage of including water of tailings, seepage water and groundwater, 3) foot of the retaining dike of TD-IV was in a location where it could be easily eroded by the Kiselica River and 4) others.

The restoration of collapsed dam (TD-IV) was enforced using new tailings generated after the incident as well as piling tailings in TD-V as shown in Figure 2.9. However, no measures have been taken against the soil and water contamination in the lower stream of the Kiselica and Zletovska Rivers.

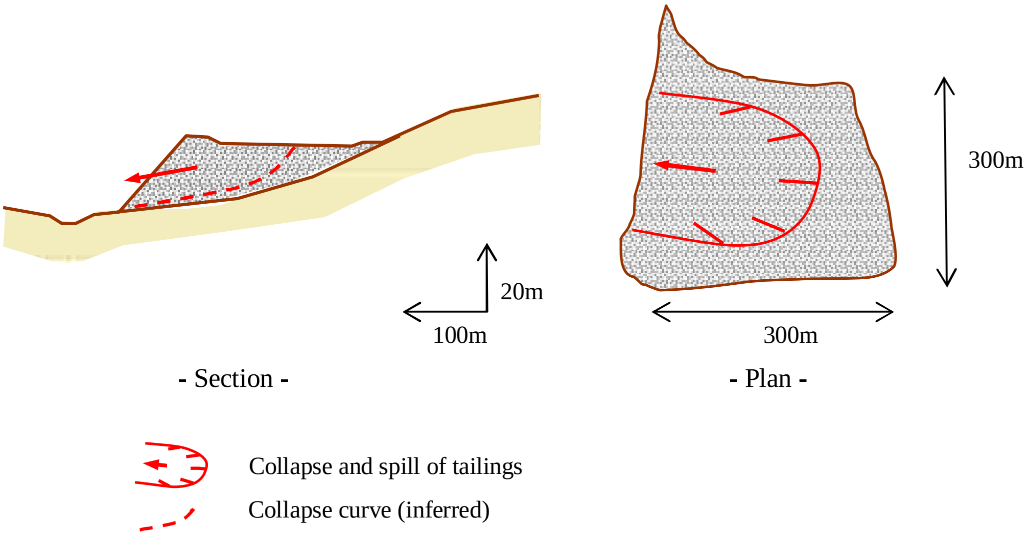


Figure 2.8 TD-IV Tailings Dam and Collapse of Tailings

c. Old Tailings Dams (TD-V) between 1976 and 1986

The restoration of collapsed dam (TD-IV) and piling tailings in TD-V were conducted between 1976 and 1986. The annual production of crude ore had reached to 470,000t in 1978.

TD-V dam were also constructed by inter piling method of flat type, and the volume of the tailings of TD-V is thought to be approximately 1,100,000m^3 as shown in Table 2.4.

Presently, the TD-IV and V areas remain with bare tailings surface except along the road of the eastern side of the area, which is locally covered by surplus soils of construction and demolition wastes in thickness of 1 to 2.5m.

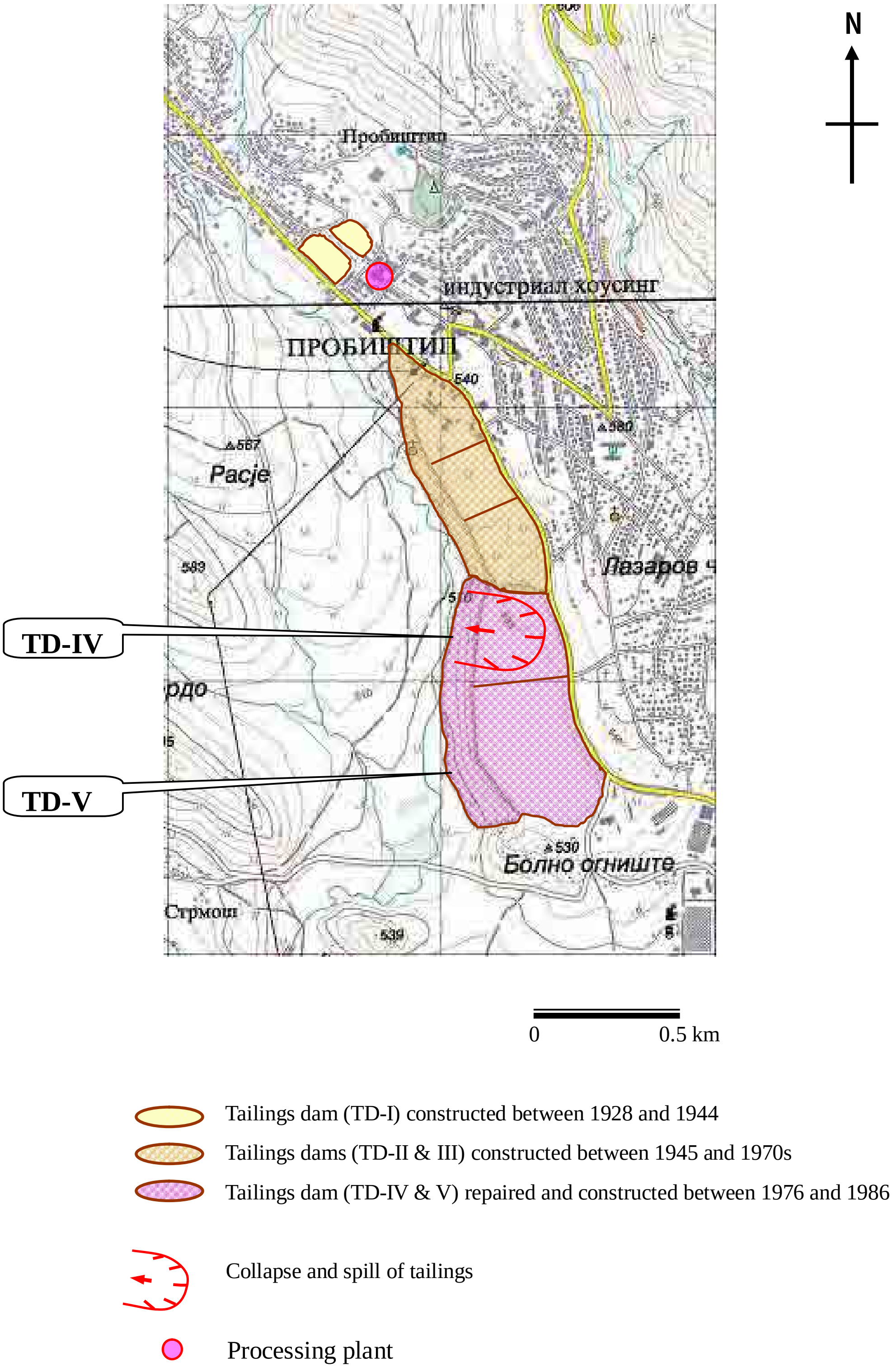


Figure 2.9 Construction of Tailings Dams between 1974 and 1986

(Drainage system)
In the Old Tailings Dams of TD-II to TD-V, several culverts were installed in the dams for the drainage of internal water and seepage water consisting of rainfall water and groundwater derived from outside of the dams. Presently, however, it is thought that they are not functioning due to collapse, and some places of strong acidic seepage are found on the slopes of dikes, but they are a small quantity of discharge.

d. New Tailings Dam after 1987

The New Tailings Dam was constructed in the lower part of the Kiselica River and is located 1.5km south of the Old Tailings Dams as shown in Figure 2.10, and tailings started to pile from 1987.

The New Tailings Dam is also constructed by inter piling method of valley type as shown in Table 2.4 and Figure 2.10.

(4) Spill Incident and its Impacts

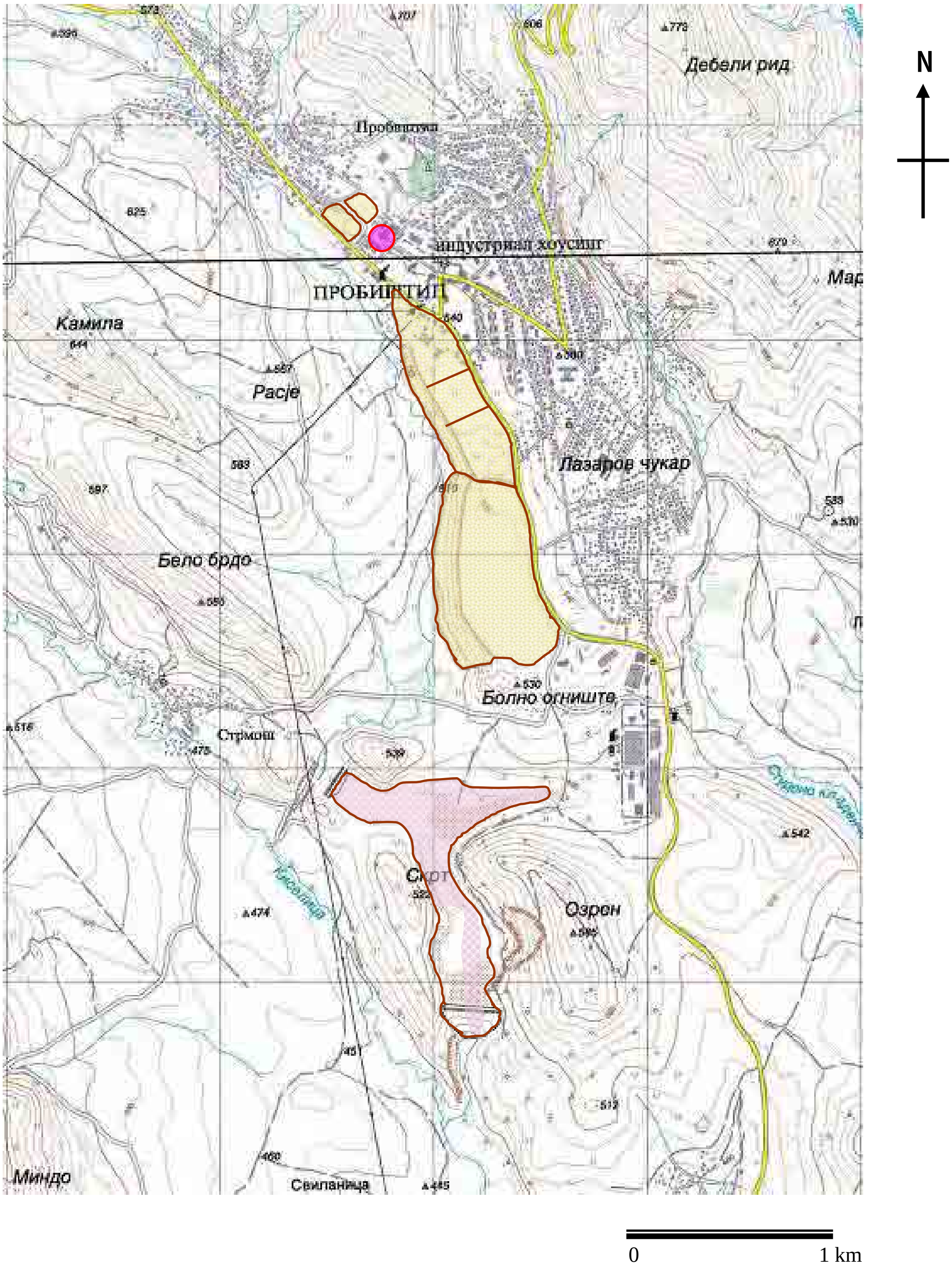
There are some reports from the local community about small tailings collapses occurring at different times in the last 40 years, and these small amounts of tailings were transported down the valley. However, the main tailings collapse occurred in 1976 and much tailings material was spilled downstream along the valley of Kiselica River.

The movement of tailings down the valley has been described as a rolling flow of tailings material. There were no human deaths as a result of the collapse, but several agricultural livestock (e.g. cattle) were lost.

There are varying reports regarding the depth of the tailings residues that covered parts of the valley in the days after the collapse, and this would of course depend on the width of the valley. In Tripitanci (located in the valley 8km south of Probistip), the tailings in the valley reached 2 to 3m deep. Further south in Pisica (14km south of Probistip), the depth of tailings was 15cm.

At the bridge over the Kiselica River (in between Buciste and Neokazi), the tailings had blocked the channel under the bridge and built up against the bridge, so that the tailings were even pushed across the road. The tailings visibly remained around the bridge for 3 to 4 years.

In 2007, there are still a few visible signs of residues in the valley and there are also varying reports about the time taken for the majority of the tailings residues to be washed away. During the first year after the tailings collapse the mining company used bulldozers to remove tailings from the river and from private land. However, it is believed that most of these removed tailings were simply placed on nearby municipal land. Over the following years, much of the tailings residues



Old Tailings Dams constructed between 1928 and 1945

Old Tailings Dams constructed between 1945 and 1986

New Tailings Dam started to pile since 1987

Processing plant

Figure 2.10 Construction of Tailings Dams after 1987 were washed away by natural processes (e.g. rain water and surface run-off). It is apparent that the majority of the tailings residues were washed away within 1 to 4 years, although under the topsoil some tailings material can still be seen around Buciste, and the P/P survey had observed evidence of residual tailings in the area.

In the Zletovica Valley, several areas have been affected in terms of agricultural production. Just to the south of the P/P area, the village of Pisica (14km south of Probistip) reportedly was not able to grow crops in several nearby areas for 3 years after the collapse, and even after 3 years, many crops had a poor yield. After the incident the local community was instructed to move livestock away from the area of contamination.

Further up the valley, the impacts on crop production were worse. For example, in Tripitanci (about 8km from Probistip), the local farmers tried to change the types of crops that they grow on the land that was affected, but even today some land does not yield agricultural crops in economical quantities, and there are a few concerns of the local community about the contamination of the crops.

In Strmos and Neokazi, which are villages nearer the tailings dams, the situation is even worse and the local community report that no plants or trees will grow on certain areas of land. Neokazi, in particular, has been impacted and continues to be affected (Strmos village is itself uphill from the tailings dam, but some areas of cultivated land down the valley near Strmos, which are farmed by people from Strmos, were greatly affected.).

Generally, there is an apparent lack of awareness of the farming community in the Zletovica River valley, in relation to the possible impacts of potentially contaminated soil. However, it is probable also, that the priority for these poorer members of the local community is to grow crops in order to gain an income or simply to have food for their families, and the fact that the crops could be contaminated is likely to be a low priority for them.

None of the people interviewed remembered any visible health impacts as a result of the tailings collapse.

2.5 Results of the 400m Grid Soil Survey

The 400m soil survey covers nearly a whole area of P/P area as shown in Figure 1.1. The 200m, 100m and 50m grids soil surveys were conducted only in the specific area of P/P area based on the results of 400m grid survey in order to clarify the area of high heavy metal concentration by narrow down method. Therefore, the Action Plan should be developed by the risk assessment using results of 400m grid soil survey, because the purpose of the Action Plan is to understand the general features of the whole area of the P/P.

2.5.1 Nature of Soil in the P/P Area

The samples are most typically brown soil, silt to clay, with exception of sandy materials especially on the hill or on the river bed. The sampling depth is mostly 30cm deep. The soil samples show a wide range of pH from 5.38 to 8.38, however, most of them (85 % of the total samples) fall within a range of 6.90 to 7.50. The samples with low pH occur in the hill area of northwest part of the P/P area, along the Zletovska River and near the tailings dam. No clear tendency of the distribution of high pH samples was observed.

2.5.2 Results of the Content Analysis of 400m Grid Samples

The content analysis of 10 heavy metals, As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn and Mn, were conducted for soil samples collected from 679 grids.

(1) Chemical Analysis Method

Soil samples for the content analysis were digested with HF and $HClO_4$ according ISO 14869-1 after drying, crushing and milling (ISO 11464), and they were determined by ICP (ISO 11885-1) for As, Cd, Co, Cr, Cu, Ni, Pb, Zn and Mn. Concerning Hg, after drying, crushing and milling (ISO 11464), soil samples were digested with HCl and HNO_3 (ISO 16772) and determined by ICP (ISO 16772).

(2) Statistical Analysis

The analytical results of the 400m grid soil samples were processed by computer for statistical treatment. In Table 2.5, the statistical values, including maximum value, minimum value, mean value and standard deviation, are shown together with the values, such as median value, upper whisker and upper fence calculated by EDA (Exploration Data Analysis by Kurzl, 1988) method. The EDA is a method conveniently used for geochemical exploration for single element analysis. It has advantages for convenient interpretation and finding the threshold values even from the data set with small populations deviated from the main body of the data. For the threshold value, the value of defining anomaly, upper fence value of EDA was taken. If the upper fence was greater than maximum values, upper whisker was chosen for the threshold value. If no clear threshold value was obtained by the EDA method, background + 2 S. D. (Standard Deviation) was considered as threshold value.

Table 2.5 Statistical Values of 400m Grid Samples

679 samples

	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Mn
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Below detection limit (%)	0.9	45.1	-	-	-	99.7	0.1	-	-	-
Maximum Value	740	46	36	420	670	0.23	280	21,000	10,000	58,000
Minimum Value	<1	<0.1	6.0	1.3	6.0	<0.1	<1	16	12	220
Mean Value (b)*1	16	0.4	19	32	31	0.05	19	82	130	1,300
Standard Deviation (log)	0.507	0.441	0.095	0.303	0.277	-	0.375	0.468	0.376	0.281
b + 2 S.D.*2	162	3.0	29.4	131	110	-	108	704	721	4,690
Median (EDA*3)	14	0.25	19.1	30.7	27	-	16.1	56.7	95.2	1,130
Upper Whisker (EDA)	36.9	1.0	23.1	57	48	-	38.5	120	158	1,490
Upper Fence (EDA)	209	0.25	35.3	166	112	-	128	286	276	2,290
Threshold Value	209	3.0	29	166	112	-	128	286	276	2,290
Above Threshold Value *4	18	51	7	6	33	-	21	79	88	60

*1:geometric mean, *2: background value + 2x standard deviation, *3:EDA Exploration Data Analysis (Kurzl, 1988)
*4 Number of samples above threshold value

(3) Concentration Map of Heavy Metals

Table 2.6 shows comparison of background values (mean value) of 400m grid soil samples with some of the reference compositions. Comparison of the background value of the P/P area with the average soil of Bowen (1979) shows that As, Co, Pb and Zn are higher in the P/P area and Cr and Ni are lower than the average soil, while the background values of Cd and Cu of the P/P area show similar value to the average soil.

Table 2.6 Background Values

	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Mn
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Mean value of 400m grid survey	16	0.4	19	32	31	-	19	81	130	1,300
Average soil*1	6	0.35	8	70	30	0.06	50	35	90	1,000
B.G Con.of Holland *2	29	0.8	9	100	36	0.3	35	85	140	-

*1 : After Bowen (1979): Environmental Chemistry of the Elements
*2: National background concentration of Holland

For the subdivision of concentration values for each heavy metal to produce the distribution maps of heavy metal concentration, the following three values are chosen to classify the P/P area into four areas of different concentration of heavy metals.

1. the values of the average soil of Bowen (1979)
2. Mean+2S.D. or Mean + S.D
3. Upper Fence or Mean+2S.D. (threshold value)

The values of the average soil of Bowen (1979) were chosen as the background values of the soil, because they were considered to be the general typical background values of the many regions. Distribution maps of heavy metal concentration are shown in Figures 2.11 to 2.20 and the characteristic features of each heavy metal are given below.

As

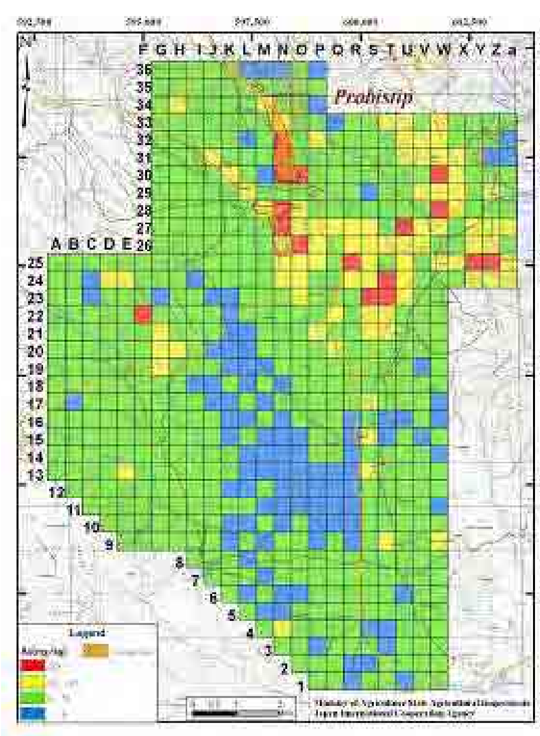


Figure 2.11 Distribution of As Concentration

Cd

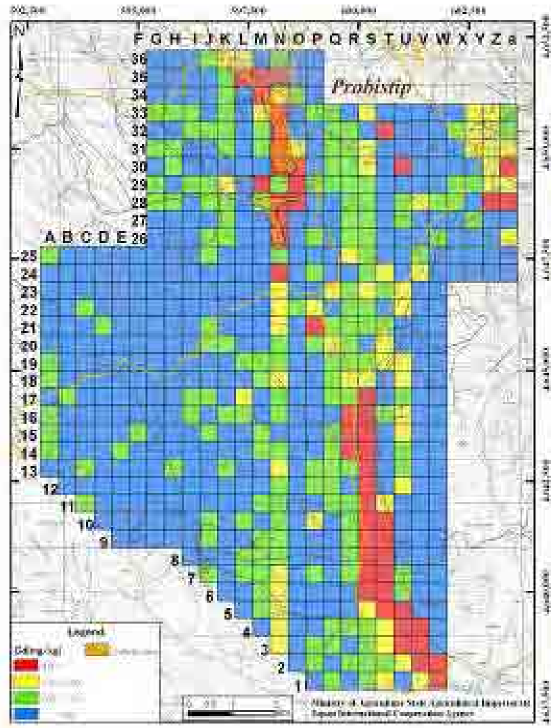


Figure 2.12 Distribution of Cd Concentration

Co

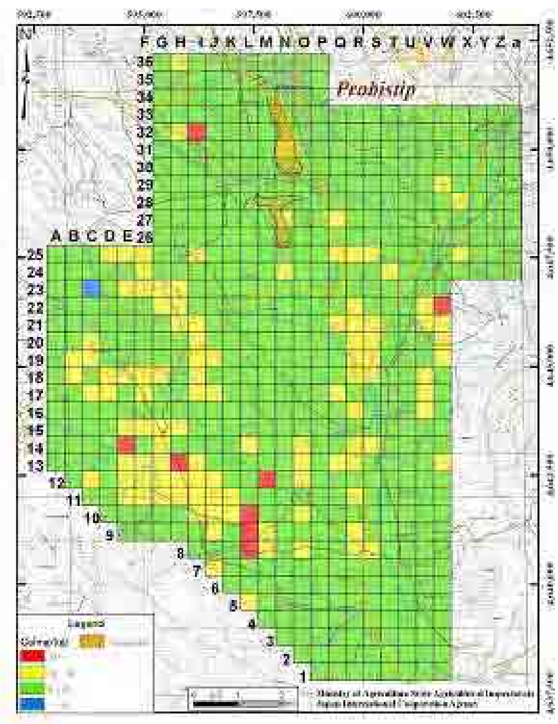


Figure 2.13 Distribution of Co Concentration

Cr

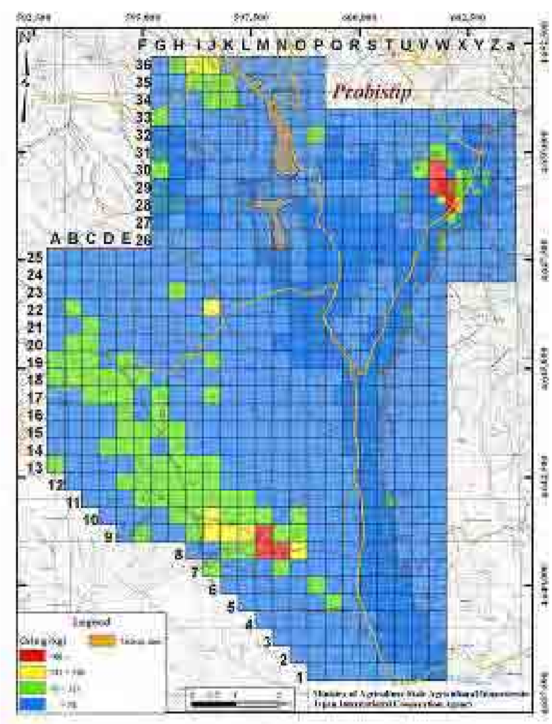
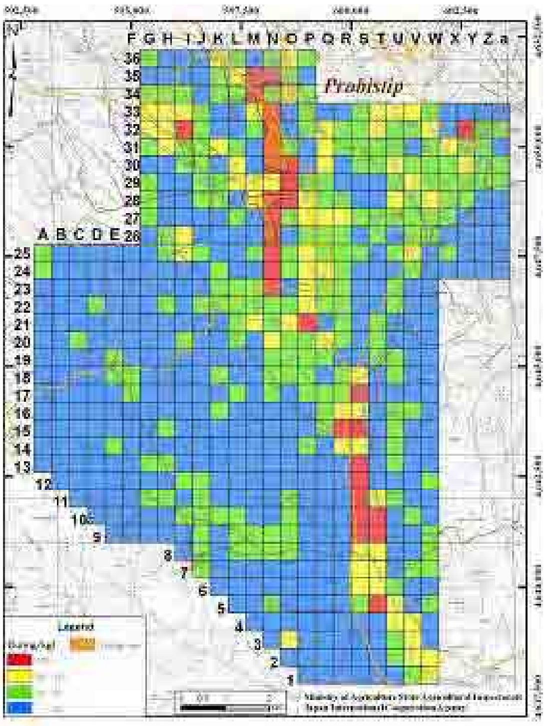


Figure 2.14 Distribution of Cr Concentration

Cu

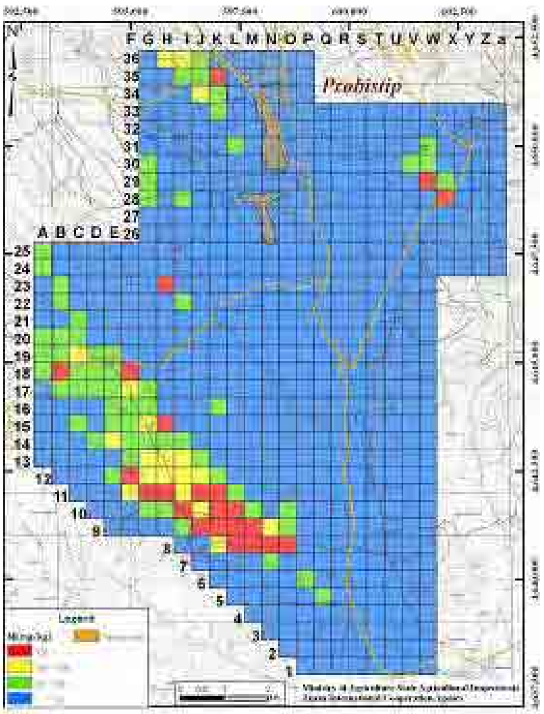


Hg

Figure 2.15 Distribution of Cu Concentration

Figure 2.16 Distribution of Hg Concentration

Ni



Pb

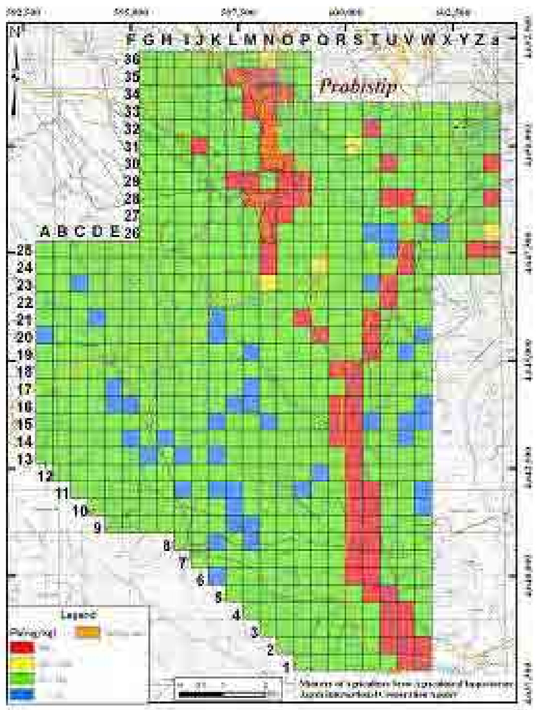
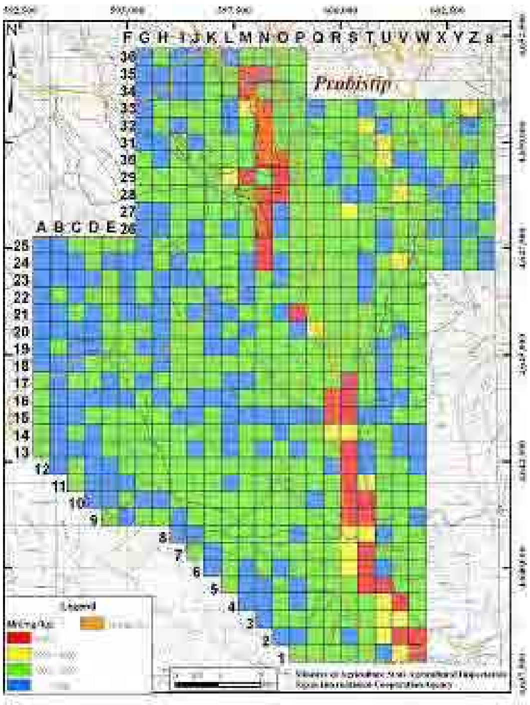


Figure 2.17 Distribution of Ni Concentration

Figure 2.18 Distribution of Pb Concentration

Zn **Mn**



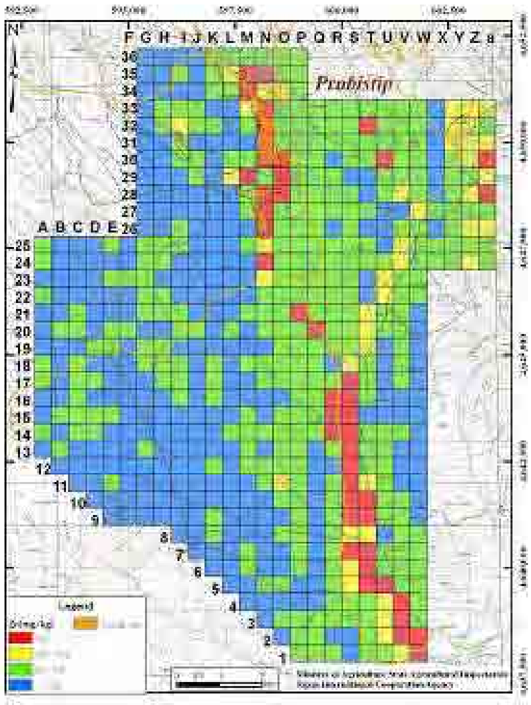


Figure 2.19 Distribution of Zn Concentration Figure 2.20 Distribution of Mn Concentration

As: The content concentration of As ranges from <1 to 740mg/kg with background value (mean values) of 16mg/kg which is higher than Bowen's average soil of 6mg/kg and lower than background value of Holland. The grids of high As concentration more than thresholds values occur in the tailings dam area and west side of the upper stream area of the Zletovska River, but they are not found in the lower stream area of the Zletovsca river where Pb and Zn high concentration grids occur. The high concentration grids, also, occur surrounded by the grids of relatively higher concentrations in the area southeast of Probistip.

Cd: The content concentration of Cd is low, ranging from <0.1 to 46mg/kg, and 45.1% of the total samples show concentration below detection limit. The background value is 0.4mg/kg, and it is similar to the Bowens average soil. The grids with high Cd concentration of more than 3mg/kg (background value+ 2 σ（S.D.) occur overlapping the area of Pb and Zn high grids in the tailings dam area, along the Kiselica River and the lower stream area of the Zletovska River.

Co: The content concentration of Co shows relatively narrow range of 6 to 36mg/kg, and 80% of the samples fall in a narrow range of 15 to 25mg/kg. A narrow range of the Co concentration and a normal distribution pattern of concentration histogram suggest that the Co values of the P/P Area show the original chemical nature of the soil of the area, reflecting the chemical nature of the bedrock without any clear evidence of the secondary enrichment. Co high concentration grids, Co values more than 29mg/kg, occur in the northwest, northeast and east parts of the area surrounded by relatively high Co grids.

Cr: The content concentration of Cr is relatively low, ranging from 1.3 to 418mg/kg with a background value of 32mg/kg, which is less than a half of the average soil of Bowen (1979), 70 mg/kg. The grids of high Cr concentration in the area occur northeast and central south of the area surrounded by the grids of relatively high Cr concentration.

Cu: Compared to Zn and Pb, the content concentration of Cu is low, ranging from 6 to 674mg/kg with background value of 31mg/kg, which is similar value to the average soil of Bowen and background concentration of Holland. Similar to Zn and Pb, high Cu concentration grids are distributed in the tailings dam area, along the Kiselica River and the lower stream area of the Zletovska River after the Kiselica River flows in.

Hg: Since only two grids show Hg concentration higher than lower detection limit of 0.1 mg/kg, Hg was excluded from statistical treatment. The two grids with Hg concentration, respectively, 0.23 and 0.11mg/kg, occur in the mountain east of Ratovica and other than these, the P/P Area is totally covered by low Hg concentration grids less than 0.06mg/kg.

Ni: The concentration of Ni in the area is relatively low, ranging from <1 to 280mg/kg with background value of 19mg/kg, which is less than half of the average soil of Bowen and background concentration of Holland. The distributions of high Ni grids with Ni values greater than 128mg/kg are observed surrounded by relatively high concentration grids in the area isolated from the areas of high Cu, Pb, Zn and Mn. The Ni high grids of the southwest area occur overlapping the distribution of Eocene sedimentary rock (E3 Unit).

Pb: The concentration of Pb is relatively high, ranging from 16 to 21,000mg/kg with background value of 82mg/kg, which is more than twice as much as the average soil of Bowen and similar value to the background concentration of Holland. The highest value of 21,000mg/kg was obtained in the abandoned tailings dam near the floatation plant of the Zletovo Mine. In addition to the main population, a population deviated to the higher concentration is clearly observed, suggesting occurrence of anomaly at the threshold value of 286mg/kg. Similar to Zn and Mn, high Pb grids with Pb values greater than 286 mg/kg occur in the residential area of Probistip including the Zletovo Mine property, the tailing dam area, and along the Kiselica River and to lower stream of the Zletovska river where spillage of tailings by the accidents in 1976 is expected.

Zn: The concentration of Zn is similar to that of Pb, ranging from 12 to 10,000mg/kg with background value of 130mg/kg, which is slightly higher than average soil of Bowen. Same as Pb, the highest value of 10,000mg/kg was obtained in the abandoned tailings dam near the floatation plant of the Zletovo Mine. From this peak, the abundances decrease abruptly but continue to as much as 10,000mg/kg, suggesting occurrence of anomaly at the threshold value of 276mg/kg.

Similar to Pb and Mn, high Zn grids with Zn values greater than 276mg/kg occur in the residential area of Probistip including Zletovo Mine property and the tailing dam area, and along the Kiselica River and lower stream of the Zletovska river where spillage of tailings by the accidents in 1976 is expected.

Mn: The content concentration of Mn is relatively high, ranging from 220 to 58,000mg/kg with background of 1,300mg/kg, which is similar to the average soil of Bowen. The samples with very high concentration of more than 30,000mg/kg occur in the tailings dam area. Other than the main population, a population deviated to higher concentration is clearly observed with threshold value of 2,290mg/kg. Similar to Cu, Pb and Zn, high Mn grids with Mn values greater than 4,680mg/kg occur in the residential area of Probistip including Zletovo Mine property and the tailing dam area, and along the Kiselica River and lower stream of the Zletovska River. Other than these, grids of slightly high Mn sporadically occur in the area between Probistip and the Zletovska River.

(4) Correlation Coefficient

As shown in the table of correlation coefficients (Table 2.7) and similar distributions of high concentration grids, the heavy metals such as Cd, Cu, Pb, Zn and Mn have close relations with high correlation coefficient of greater than 0.600. Since the Zletovo Mine is Zn-Pb mine, these heavy metals are considered to represent the mining activities of the P/P area. Furthermore, high concentration grids of these occur in the tailings dam area, along the Kiselica River and in lower stream area of the Zletovska River where tailings materials spilled over by the collapse of the tailings dam.

Ni, on the other hand, shows very good correlation with Cr (0.823), and Cr-Co and Ni-Co show relatively good correlations (grater than 0.400). Ni, Cr and Co do not show clear relations with the above heavy metals (Cd, Cu, Pb, Zn, Mn) with low correlation coefficients.

Table 2.7 Correlation Coefficient of Content Value of the Heavy Metals

	As	Cd	Co	Cr	Cu	Ni	Pb	Zn	Mn
As	1.000								
Cd	0.224	1.000							
Co	-0.057	-0.033	1.000						
Cr	-0.081	-0.030	0.444	1.000					
Cu	0.338	0.624	-0.042	-0.132	1.000				
Ni	-0.101	-0.125	0.439	0.823	-0.138	1.000			
Pb	0.371	0.787	-0.126	-0.108	0.754	-0.233	1.000		
Zn	0.293	0.828	-0.046	-0.099	0.728	-0.216	0.897	1.000	
Mn	0.262	0.748	0.066	-0.046	0.716	-0.140	0.804	0.855	1.000

very good correlation, good correlation

2.6 River Bottom Sediments Survey

River bottom sediments were collected at the center and both sides of stream. A total of 6 samples, three samples in the Zletovska River and three samples in the Kiselica River were collected. In addition to the river bottom sediments, surface water samples were collected at the same sites. The analytical results of the river sediments are given in Table 2.8. Although the chemical nature of stream sediments and soil are different, analytical results of the river bottom sediments are shown together with the average soil of Bowen (1979) as Reference Values.

Table 2.8 Analytical Results of River Bottom Sediments

	River	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Mn
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
BS-01	Zletovsca	22	4	20	30	61	<0.1	15	510	1,000	4,900
BS-02	Zletovsca	21	4	19	41	48	<0.1	21	380	800	3,300
BS-03	Zletovsca	32	4	17	21	51	<0.1	10	450	1,000	3,800
BS-04	Kiselica	120	13	14	8.9	160	<0.1	8.1	1,500	3,000	14,000
BS-05	Kiselica	33	4	16	22	77	<0.1	13	840	880	4,500
BS-06	Kiselica	220	0.11	11	8.2	290	<0.1	2.5	1,600	330	1,100
Average Soil*		6	0.35	8	70	30	0.06	50	35	90	1,000

*: By Bowen (1979)

The three samples (BS-01, BS02 and BS-03) of the Zletovska River show similar values of Pb (380 to 510mg/kg) and Zn (800 to 1,000mg/kg) concentrations, both of them being high. Although BS-03 was collected in the upper stream area before the Kiselica River flows in, where enrichment of heavy metals caused by the tailings dam and the battery factory is not expected, it shows similar values to the 2 samples (BS-01 and BS-02) collected in the lower stream area after the Kiselica River flows in.

The three samples of Kiselica River were, respectively, collected in areas near the mouth of the Zletovska River (BS04), down stream area from the new tailings dam (BS05) and upper stream area of the tailings dams (BS06). The three samples have high concentrations of As, Cu, Pb and Zn. Among these three, heavy metal concentrations are lowest in BS-05, which was collected in the down stream area from the new tailings dam. A possible reason for this is that the tailings materials spilled by the collapse of the Tailings Dam in 1976 have been mostly washed away in that area and current accumulation of tailing material from the tailing dam is not significant. BS04, on the other hand, has high concentrations of Pb, Zn, Mn, respectively, 1,500, 3,000 and 14,000 and some tailings materials of the incident may still remain in that site. Although BS-06 was collected in the upper stream area from the tailings dam and battery factory, the concentration of As, Cu and Pb are highest. The source of the high heavy metal concentrations in the river bottom sediments at this site is attributed to the old mining activities from ancient ages in the upper stream area of the north of Probistip.

2.7 Surface Water Survey

Surface water samples were collected at the center or at the fastest point of the flow in the river. A total of 6 samples, three samples in the Zletovska River and three samples in the Kiselica River were collected at the same sampling sites of the river bottom sediments.

The analytical results are shown on Table 2.9 together with the results of pH and Electrical Conductivity (EC) measurements. The reference values shown on the table were taken from the Environmental Standard for Water of Macedonia except for Cu and Mn. For these two heavy metals, Guideline Value of WHO was taken.

The analytical results of three water samples (SW-01, SW-02 and SW-03) from the Zletovska River give relatively low concentrations of heavy metals, showing values below the Reference Values except Mn. The concentrations of Mn are high, 0.20 and 0.13mg/L, for the two samples (SW-01 and SW-02) collected in the lower stream area after the Kiselica River flows in. For the sample collected in the upper stream of the Zletovska River, before the Kiselica River flows in, none of the heavy metal exceeds the reference values.

Table 2.9 Analytical Results of Surface Water

date of sampling: 15-Aug-06

No	River	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Mn	pH	EC
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		mS/m
SW01	Zletovska	<0.003	<0.001	<0.001	<0.001	<0.002	<0.0001	<0.002	0.002	0.03	0.20	7.80	36.4
SW02	Zletovska	<0.003	<0.001	<0.001	<0.001	<0.002	<0.0001	<0.002	0.003	0.02	0.13	8.04	32.7
SW03	Zletovska	<0.003	<0.001	<0.001	<0.001	<0.002	<0.0001	<0.002	0.006	0.003	0.05	8.15	19.2
SW04	Kiselica	<0.003	<0.001	<0.001	<0.001	0.003	<0.0001	<0.002	<0.001	0.13	0.99	7.76	154.1
SW05	Kiselica	0.005	<0.001	<0.001	<0.001	0.006	<0.0001	<0.002	0.009	0.51	9.20	7.24	79.4
SW06	Kiselica	0.011	0.009	<0.001	<0.001	0.063	<0.0001	<0.002	0.015	0.76	1.60	6.85	99.5
Reference value		0.03	0.01	0.1	0.05	0.2	0.0002	0.05	0.01	0.1	0.05		

Reference Value were taken from Environmental Standard for Water of Macedonia (As, Cd, Co, Cr, Hg, Ni, Pb, Zn) and WHO (Cu,Mn)
NGERV: Number of grids exceeding the referrence value

All of the three samples of the Kiselica River show much higher concentration of Zn and Mn, exceeding the Reference Values, compared to the samples of the Zletovska River. Mn concentration of SW-05, collected in the lower stream area from the tailings dam shows the highest value, reaching to 9.21 mg/L.

For the samples collected in the lower stream area from the tailings dam, SW-04 and SW-05, only Zn and Mn concentrations exceed the reference value. Although the sample SW-06 was collected in the upper stream area from the tailings dams and the battery factory, concentration of Pb, in addition to Zn and Mn, exceeds the Reference Values and Cu, Pb and Zn are the highest among the six samples. Same as the river bottom sediments results, the source of the high Pb, Zn and Mn concentrations of the surface water at this site is attributed to the old mining activities from ancient ages in the upper stream area of the north of Probistip.

2.8 Monitoring Wells and Groundwater

2.8.1 Groundwater Survey of the Monitoring Wells

The groundwater of the monitoring borehole was collected once in a month starting from August 2006 to January 2007. At the collection of water, measurement of water head depth, pH and EC were carried out. Table 2.10 shows average values of 6 months of heavy metals and pH and EC values for each monitoring borehole basis. The standard values were taken from the Environmental Standard for Water of Macedonia Class 1 (As, Cd, Co, Cr, Hg, Ni, Pb, Zn, Mn: Official Gazette of the Republic of Macedonia, No.18-99) and guideline value of WHO (Cu: WHO, 2004).

Table 2.10 Average Values of the Heavy Metal Concentration in Groundwater

	River		As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Mn	pH	EC
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		mS/m
MBH01	Zletovska	Average	0.003	0.0031	0.035	0.002	0.121	0.00005	0.012	0.13	0.31	1.5	6.91	33
		Relative to STD	0.10	0.31	0.35	0.032	0.60	0.25	0.24	13	3.1	30		
MBH02	Zletovska	Average	0.002	0.0029	0.031	0.009	0.108	0.00005	0.012	0.34	0.34	3.0	7.30	89
		Relative to STD	0.08	0.29	0.31	0.187	0.54	0.25	0.24	34	3.4	60		
MBH03	Zletovska	Average	0.004	0.1181	0.077	0.030	0.213	0.00007	0.043	0.51	17	65	6.43	95
		Relative to STD	0.15	12	0.77	0.598	1.07	0.35	0.86	51	167	1297		
MBH04	Zletovska	Average	0.002	0.0006	0.021	0.002	0.042	0.00007	0.056	0.013	0.10	6.4	7.32	49
		Relative to STD	0.06	0.06	0.21	0.047	0.21	0.33	1.11	1.3	0.98	129		
MBH05	Zletovska	Average	0.002	0.0010	0.005	0.001	0.086	0.00005	0.003	0.15	0.20	0.24	7.61	44
		Relative to STD	0.05	0.10	0.05	0.017	0.43	0.25	0.06	15	2.0	4.7		
MBH06	Zletovska	Average	0.002	0.0015	0.011	0.002	0.107	0.00005	0.004	0.087	0.48	0.54	6.39	78
		Relative to STD	0.05	0.15	0.11	0.049	0.53	0.25	0.07	8.7	4.8	11		
MBH07	Kiselica	Average	0.002	0.0010	0.023	0.009	0.133	0.00007	0.049	0.077	0.35	15	7.12	255
		Relative to STD	0.06	0.10	0.23	0.175	0.66	0.37	0.99	7.7	3.5	306		
MBH08	Kiselica	Average	0.007	0.0029	0.009	0.003	0.184	0.00005	0.007	0.13	0.22	2.0	7.34	107
		Relative to STD	0.24	0.29	0.09	0.052	0.92	0.25	0.14	13	2.2	41		
MBH09	Kiselica	Average	0.002	0.0018	0.015	0.007	0.107	0.00007	0.019	0.21	0.18	7.4	7.18	117
		Relative to STD	0.08	0.18	0.15	0.145	0.54	0.33	0.38	21	1.8	148		
MBH10	Kiselica	Average	0.005	0.0007	0.008	0.002	0.107	0.00005	0.017	0.11	0.14	2.8	7.29	92
		Relative to STD	0.17	0.07	0.08	0.045	0.53	0.25	0.35	11	1.4	57		
MBH11	Kiselica	Average	0.014	0.0005	0.006	0.001	0.036	0.00005	0.007	0.014	0.086	0.42	7.32	86
		Relative to STD	0.48	0.05	0.06	0.024	0.18	0.25	0.15	1.4	0.86	8.4		
MBH12	Kiselica	Average	0.006	0.0005	0.007	0.001	0.083	0.00005	0.007	0.18	0.14	0.70	7.44	74
		Relative to STD	0.18	0.05	0.07	0.026	0.42	0.25	0.15	18	1.4	14		
R.V. (Reference Value)			0.03	0.01	0.1	0.05	0.2	0.0002	0.05	0.01	0.1	0.05		

Standard: Taken from Environmental Standard for Water of Macedonia (As, Cd, Co, Cr, Hg, Ni, Pb, Zn, Mn) and guideline value of WHO (Cu)

Average: Avalage value of six month

: Exceeding the Standard Value

Relative to STD=Average Value devided by the Standard Value

The groundwater observed at all the sites are free groundwater, and confined groundwater was not observed. As mentioned previously, the water table does not change significantly through 6 months of monitoring, showing the changes of 20 to 50cm from August 2006 to January 2007.

Pb, Zn and Mn show significantly high concentrations in the groundwater of the Zletovska and Kiselica Rivers Area. The distributions of these heavy metals in groundwater are summarised below.

Pb: Pb concentrations along the Zletovska River increase toward downstream. It becomes the highest at MBH03, especially after the Kiserica River flows in, then it becomes lower at the most down stream site of the MBH06. On the E-W cross section, the Pb concentration of MBH05 located on the west side is higher compared with MBH4 of the east side with Pb concentration close to the Standard Value.

Zn: Along the Zletovska River, Zn values are exceptionally high at MBH03 and two boreholes located in the upper stream area from this and one borehole located in the lower stream area from this show similar Zn concentrations. The reason for the high concentration of Zn at MBH03 is attributed to the accumulation of tailings material in that location. On the E-W sections, the boreholes of MBH04 and MBH05, drilled on the east and west sides of the river, show lower values of close to the Standard Value.

Mn: On the Zletovska River profile, the Mn concentration of groundwater increases towards the lower stream and reach to exceptionally high value of 65ml/L at MBH03, then abruptly decreases at MBH06. The high Mn concentration at MBH03 is attributed to the accumulation of the tailings materials in the area. On E-W section, MBH4 located on the east side of the river shows very high Mn concentration compared with MBH05 of the west side of the river.

2.8.2 Additional Groundwater Survey

For further understanding of the heavy metal concentrations of groundwater and surface water in the area of the P/P, additional survey of the groundwater and surface water covering the whole area of the P/P was conducted in the Phase 3 Survey.

Sampling of 126 water samples, consisting of 95 well/spring water samples collected from 29 villages/communities and 31 surface water samples, was conducted during June 2007.

For well and spring samples, since the concentrations of heavy metals at each well and spring do not change significantly within each village, average values of the heavy metal concentration were calculated as shown in Table 2.11.

Among 10 heavy metals, Cd, Cr, Cu, Hg do not show any significantly high concentrations, each of them, respectively, ranging from 0.00004 to 0.0017mg/L, <0.005 to 0.034mg/L, 0.005 to 0.18mg/L, <0.0001 to 0.00018mg/L, and none of the samples exceeds the Water Quality Standard and the Standard of Drinking Water.

As: All the samples, including well/spring and river, show similar As concentrations, all of them falling in a narrow range of 0.008 to 0.015mg/L, except 2 samples of RS01 (0.020mg/L) and RS06 (0.039mg/L). RS01 was collected in the Koritnica River, immediately lower stream of mine workings and RS06 was collected below at northwest of Stromos. Among all the samples only

Table 2.11 Statistical Values and Reference Values of Water for the Pilot Project

(Well and spring water: 95 samples from 29 villages, surface water samples: 31 samples)

		As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Mn
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Well and Spring	Maximum	0.015	0.0013	0.40	0.034	0.028	0.00018	0.068	0.028	0.29	0.019
	Minimum	0.008	0.0001	0.028	<0.005	0.006	<0.0001	0.017	0.006	<0.01	0.004
	Average	0.011	0.0003	0.067	0.010	0.010	-	0.035	0.015	0.015	0.009
	NSE W.Q.*	0	0	6	0	0	0	4	77	3	0
	NSE D.W.**	63	0	57	0	0	0	95	77	0	0
	NVE D.W.***	22	0	17	0	0	0	29	26	0	0
Surface Water	Maximum	0.039	0.0017	1.06	0.022	0.18	<0.0001	0.79	0.058	5.8	33
	Minimum	0.008	0.00004	0.008	<0.005	0.005	<0.0001	0.44	0.007	<0.01	0.006
	Average	0.013	0.0004	0.11	0.010	0.019	-	0.58	0.016	0.44	4.0
	NSE W.Q.*	1	0	9	0	0	0	31	24	6	21
W. Q.****		0.03	0.01	0.1	0.05	0.2	0.0002	0.05	0.01	0.1	0.05
D. W. *****		0.01	0.003	0.05	0.05	2	0.001	0.02	0.01	3	0.05

NSE W.Q.*: Number of samples exceeding the Water Quality of Macedonia

NSE D.W.**.: Number of samples exceeding Standard of Drinking Water

NVE D.W.***: Number of village exceeding Standard of Drinking Water

W.Q. ****:Standard Value taken from the Water Quality Standard of Macedonia (Class I of Regulation for Classification of Water, Macedonia) except Cu which was taken from the guideline value of WHO.

D.W. *****:Standard of Drinking Water, Macedonia (Official Gazette 57/04)

RS06 has As concentration exceeding the Water Quality Standard, but As concentrations of the well/spring water and river water are generally high with average values of 0.011 and 0.013mg/L, respectively. None of the well and spring water has As concentration exceeding the Water Quality Standard, however, most of the samples (67%) show As value exceeding Standard of Drinking Water of Macedonia.

Co: Co concentration of P/P area is high, and river water, ranging 0.008 to 1.06mg/L at an average of 0.11mg/L, shows higher concentration than well/spring water, 0.028 to 0.40mg/L at an average of 0.067mg/L. Among 95 samples of spring/water, 6 and 57 samples, respectively, exceed the Standard of Drinking Water and the Water Quality Standard.

Ni: Ni concentration of the P/P area is high, and it is more than 10 times higher in river water, ranging 0.44 to 0.79mg/L at an average of 0.58mg/L, than well/spring water, ranging from 0.017 to 0.068mg/L at an average of 0.035mg/L. Ni is known to be easily absorbed by soil grains during flowing underground.

Pb: Pb concentration of well/spring and river waters are similarly high, showing values of, respectively, 0.006 to 0.028mg/L at an average of 0.015mg/L and 0.007 to 0.058mg/L at an average of 0.016mg/L. The Water Quality Standard and the Standard of Drinking Water are same, being set at 0.01mg/L. The most of the samples of well/spring, 77 samples out of 95 samples, exceed the Water Quality Standard and the Standard of Drinking Water.

Zn: Many of the water samples of P/P area, 86 samples out of 126 samples, have Zn concentration less than detection limit of 0.01mg/L, however some of the samples show a high concentration, reaching 0.29mg/L for well/spring samples and 5.8mg/L for river water samples. The concentrations of Zn is higher in river samples, ranging from <0.01 to 5.8mg/L at an average of 0.44mg/L, than well/spring samples, ranging from <0.01 to 0.29mg/L at an average of 0.02mg/L.

Mn: Well/spring samples show relatively low concentrations, ranging from 0.004 to 0.019mg/L at an average of 0.009mg/L, while river water shows more than 10 times higher concentration than well/spring water ranging from 0.006 to 33mg/L at an average of 4.0mg/L. None of the well/spring water exceeds the Water Quality Standard and the Standard of Drinking Water.

The water quality of well/spring water is low, As, Co, Ni and Pb concentrations being higher than the Standard of Drinking Water in most of the well and springs. It is serious problem that more than half of the wells/springs in the P/P area are still used as a source of drinking water by the local residents in spite of the fact that the most of them are not appropriate for drinking. The situation of river water is similar, showing the Ni, Pb and Mn concentrations exceeding the Water Quality Standard at the most of the locations.

2.9 Tailings Survey

For understanding the tailings materials of the tailings dam, two boreholes, one each on the old tailings dam and the new tailings dam, were drilled. The thickness of the tailings material penetrated by drilling was 23.45m at the old tailings dam and 27.30m at the new tailings dam. At the old tailings dam, tailings are covered by soil of 1.10m thick. The tailings material consists of pale brown to brown silt to sand at the both of the tailings dams. The tailings were collected at 2m interval from the drill core and they were sent for chemical analysis.

Comparing both tailings dams, Zn is much higher and Cu is slightly high in the old tailings dam than in the new tailings dam. While As is slightly lower in the old tailings dam than in the new tailings dam. A systematic chemical variation in vertical direction is not clearly observed in both of the tailings dam.

2.10 Crops Survey

2.10.1 Crops Survey in 2006

A total of 104 crop samples, consisting of 84 wheat, 16 corn and 4 rice samples, were collected. Comparing each crop based on the mean value, wheat is characterized by higher concentrations of Cr, Hg, Ni, Zn and Mn than those of corn and rice (Table 2.12). Particularly, the mean concentration value of Hg and Ni shows 3 times more than that of corn and rice. Although the mean concentration value of Zn and Mn are higher in wheat than in corn and rice, they are not significantly high.

Rice, on the other hand, is characterized by higher concentration of As, Cd, Co and Cu than those of wheat and corn. Corn seems to have intermediate heavy metal concentrations between wheat and rice. In particular, rice shows the mean concentration value of Cd and Co more than 4 times greater than those of wheat and corn. The mean concentration value of As and Cu do not show large difference. Although corn has slightly lower concentration of Pb compared to other crops, three crops show similar Pb content. Each of the crops of the P/P area has characteristic heavy metal concentration, slightly different from each other.

Table 2.12 Statistics of Content Analytical Results of Crops

(1) Wheat (84 samples)

Items	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Mn
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	µg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Maximum	0.94	0.039	0.85	1.7	4.3	23	47	1.9	91	44
Minimum	<0.25	<0.005	<0.05	<0.05	1.3	<0.4	<0.25	<0.05	31	32
Mean	0.26	0.005	0.15	0.38	2.3	1.4	2.9	0.27	47	39
SD (s) *1	0.19	0.006	0.16	0.29	0.64	3.2	9.2	0.40	12	2.3
Mean+1s	0.45	0.011	0.31	0.67	2.9	4.6	12	0.67	59	41
Mean+2s	0.64	0.017	0.47	0.96	3.5	7.8	21	1.1	71	43
Mean+3s	0.83	0.022	0.64	1.2	4.3	11.0	30	1.5	82	45

*1 SD (s): Standard deviation.

(2) Corn (16 samples)

Items	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Mn
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	µg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Maximum	<0.25	<0.005	0.26	0.28	4.2	4.9	1.1	0.37	25	40
Minimum	<0.25	<0.005	<0.05	<0.05	2.2	<0.4	<0.25	<0.05	18	19
Mean	<0.25	<0.005	0.09	0.19	2.9	0.49	0.63	0.17	23	23
SD (s) *1	0.00	0.000	0.09	0.05	0.48	1.2	0.31	0.13	2.1	6.7
Mean+1s	-	-	0.18	0.24	3.4	1.7	0.94	0.30	25	30
Mean+2s	-	-	0.28	0.29	3.8	2.8	1.2	0.43	27	36
Mean+3s	-	-	0.37	0.34	4.3	4.0	1.6	0.56	29	43

(3) Rice (4 samples)

Items	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	Mn
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	µg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Maximum	0.42	0.16	0.72	0.25	6.3	<0.4	0.91	0.32	37	26
Minimum	0.33	0.11	0.51	0.16	3.6	<0.4	0.72	0.18	23	22
Mean	0.37	0.13	0.60	0.20	4.8	<0.4	0.82	0.25	29	24

(Comparison with the Macedonian Standard Values)

The analytical results of crop analysis were compared with some of the key values. There are mainly two key values for crops currently used in Macedonia. The one is Standard: Maximum Levels of Heavy Metals in Foodstuffs (Macedonia, 2005) and the other is Reference Value: Maximum Allowed Concentration in foodstuffs (Former Yugoslavia, 1992). For assessing the results of the crops analysis, Cd (0.2mg/kg) and Pb (0.2mg/kg) values of the Maximum levels of heavy metals in foodstuffs of Macedonia were taken as the Standard Value, and Hg (50µg/kg) and

As (1mg/kg) values of the Maximum allowed concentration of Former Yugoslavia (CFPJ, 1992) were taken as the reference value..

None of wheat, corn and rice samples exceeds the key values of As (1mg/kg), Cd (0.2mg/kg) and Hg (50μg/kg), however, 30 samples (36%) of wheat, 8 samples of corn and 3 samples of rice exceed the Pb Standard Values.

The wheat samples exceeding the Standard Values of Pb are mainly distributed in the areas of west of Kiselica River and west of Belosica river, to the south west of the tailings dams (Figure 5.35). Since concentrations of Pb in content and elution analysis are not particularly high in that area, an effect of heavy metal high dust may be attributed for high concentration of Pb in the areas. The most of the corn and rice samples were collected in the area along the Kiselica and Zletovska Rivers, and high concentration of Pb in corn and rice samples were caused by soil and water with high concentration of heavy metals.

2.10.2 Additional Wheat Survey

In Phase 3 (2007), chemical analysis of 32 wheat samples and soil samples was conducted to examine yearly variation of Pb in wheat and relations of Pb concentration between wheat and soil.

The sampling was conducted using the 400m grid system of soil survey of the P/P area. The location of the sampling was decided based on the results of 2006 survey and both of wheat and soil samples were collected at the center of the each grid. The chemical analyses of wheat and soil were conducted for three elements of Pb, Cd, As. Both content and elution analyses were carried out for soil samples.

Pb concentration of wheat is high, ranging from <0.05 to 0.36mg/kg at an average of 0.12mg/kg, which is lower than results of Phase 2 survey with average value of 0.27mg/kg. The samples with Pb concentration exceeding the Standard Value are seven (22%), which is less than Phase 2 survey with 36 % of the samples being exceeding the Standard Value. Cd and As are low, most of the samples shows concentrations less than detection limit of, respectively <0.005 and <0.25mg/kg, and none of the sample reaches to the Standard and Reference Values of 0.2 and 1.0mg/kg.

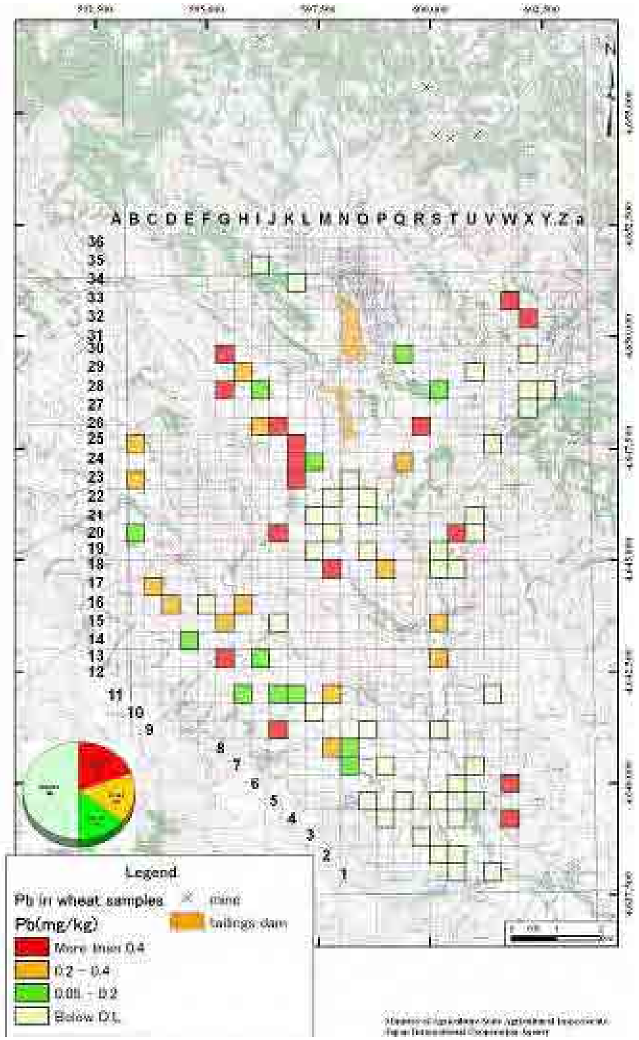
Comparison of Pb concentration between 2006 and 2007 samples collected from the same grid shows that Pb concentration of 2007 samples are consistently lower than that of 2006 samples (Figure 2.21).

The distribution map of Pb concentration of wheat shows that distributions of Pb high wheat samples with concentrations greater than Standard Value are clearly less in 2007 samples compared with 2006 samples and that, in both of the cases, Pb high wheat are distributed in the same area, south west of the tailings dams.

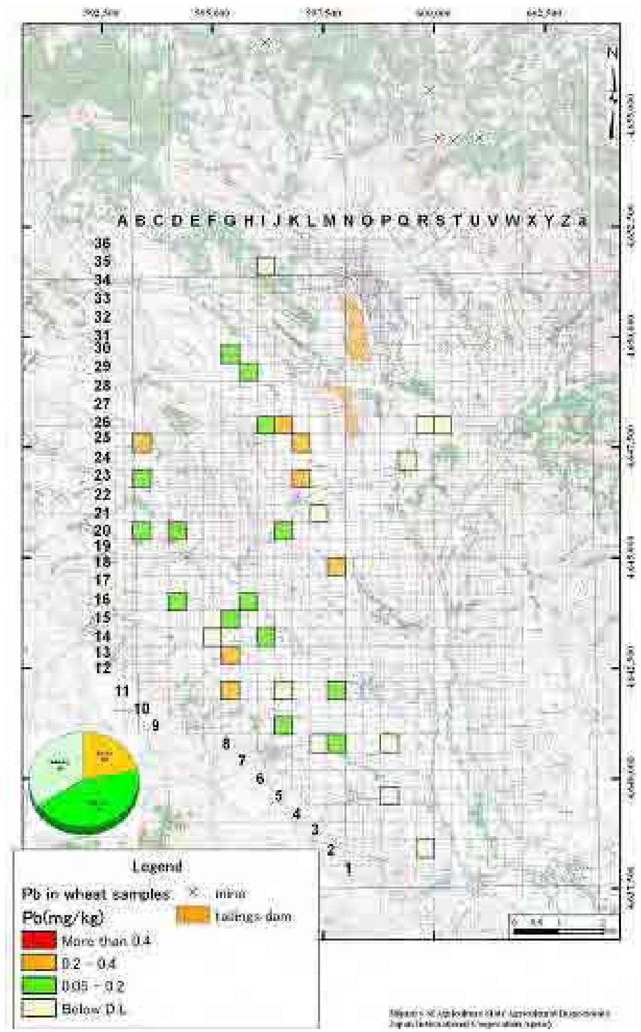
The results of 32 wheat and soil samples do not show any clear chemical relation of Pb between wheat and soil samples. The consistently lower concentrations of Pb in 2007 wheat samples than those of 2006 samples probably suggest a yearly variation of Pb concentration in wheat.

The results of the additional wheat analysis are summarised as blow:

1. Yearly variations of Pb concentration in wheat seems to be caused by factors such as weather and wind, and long term monitoring is necessary to understand the Pb concentration of wheat.
2. Pb concentration of soil, including content and elution, does not play key role to determine Pb concentration of wheat. Combination of factors such as soil, groundwater, dust, etc. must be considered for understanding the mechanism of Pb concentration of wheat.
3. There are some areas where Pb concentration of wheat is always high. These areas are not appropriate for cultivation of wheat as long as this environmental situation continues.



Results of 2006



Results of 2007

Figure 2.21 Distribution of Pb Concentration in Wheat

CHAPTER 3 COMPREHENSIVE ANALYSIS OF CONTAMINATION IN THE PILOT PROJECT

CHAPTER 3 COMPREHENSIVE ANALYSIS OF CONTAMINATION IN THE PILOT PROJECT

3.1 Soil Contaminated Zones in the Pilot Project Area

The high concentration of heavy metals in the Pilot Project (P/P) area can be classified into two groups, namely As-Cd-Cu-Pb-Zn-Mn and Co-Cr-Ni Groups. The As-Cd-Cu-Pb-Zn-Mn Group clearly shows a relation to the soil contamination derived from the spill incident of the tailings dams in 1976 as well as Pb-Zn mineralisation locally found in the north eastern part of the area. Therefore, high concentration of the As-Cd-Cu-Pb-Zn-Mn Group can be attributed to soil contamination by human cause except high concentration of Zn-Pb-Cd in the north eastern part of the area.

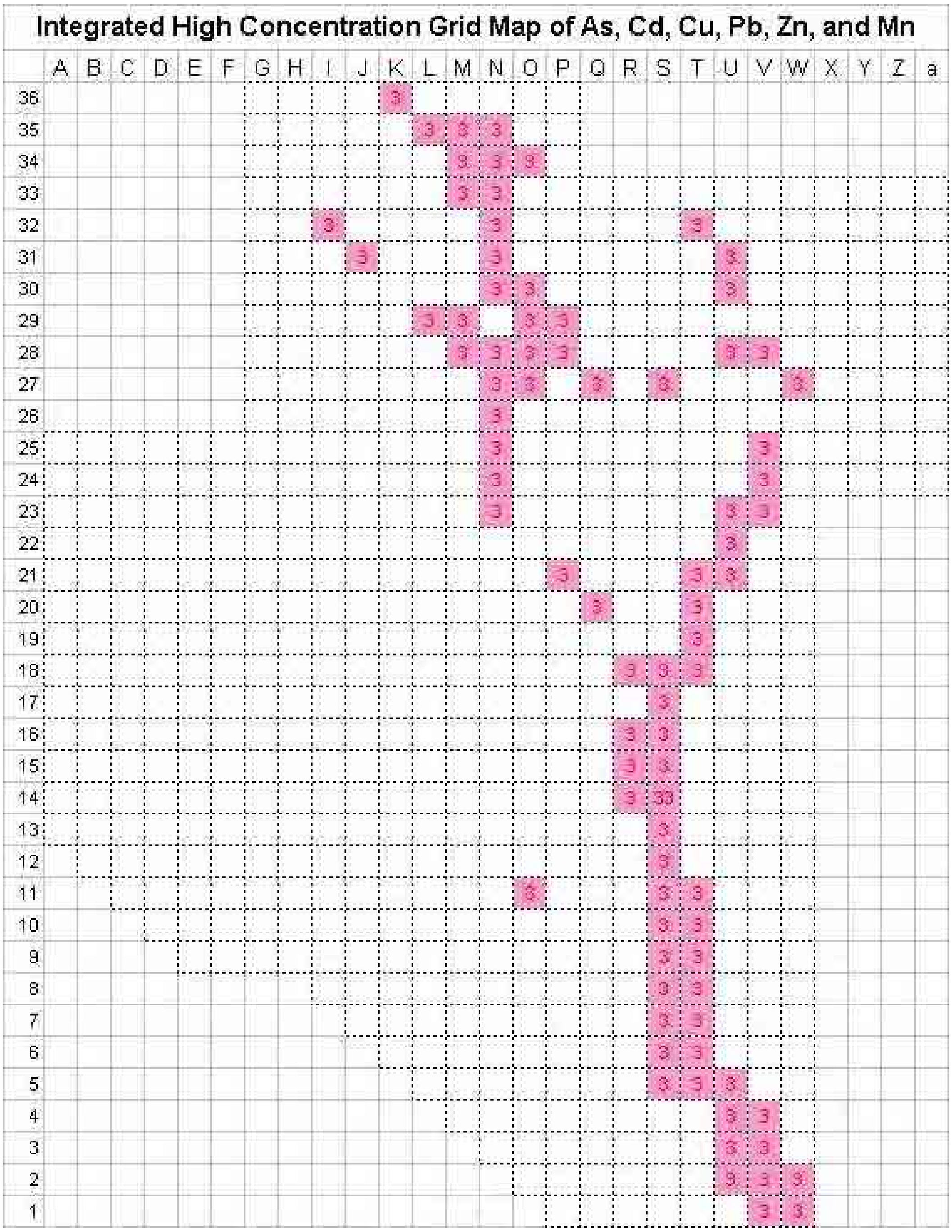
On the other hand, as discussed in Chapter 2, the Co-Cr-Ni Group, especially located in the southwestern part of the area, is considered to be originated from the sedimentary rocks of the Tertiary formation. Therefore, high concentration of the Co-Cr-Ni Group is naturally caused and is excluded from farther consideration in the Study.

The integrated high concentration grid map of heavy metals of As-Cd-Cu-Pb-Zn-Mn (400m grids) is shown in Figure 3.1. Most of the high concentration grids are distributed along the Kiselica, Koritnica and Zletovska Rivers as shown in Figure 6.2 plotted in the topographical map.

The Kiselica River flows to the west side of Old Tailings Dam and along New Tailings Dam. The high concentration grids are particularly distributed around Old Tailings Dam (TD-I) and processing plant, western and southern parts of the tailing dams (TD-II, III, IV and V), around the battery factory, and lower and lowermost (after bridge) stream of the Kiselica River. The soil contamination extending to the western part of the tailings dams seems to be affected by dust of the tailings materials migrated from tailings dams by wind.

The Koritnica River is flowing from the Zletovo Mine site. Fragments and gravels of ore and mineralised rocks containing much Pb and Zn ore minerals are found in the bottom sediments along the river. Although some of the contaminated fragments and gravels might be derived from natural causes, most of them are likely to have occurred from mining activity. The contaminated sediments are also flowing from Koritnica into the Zletovska River.

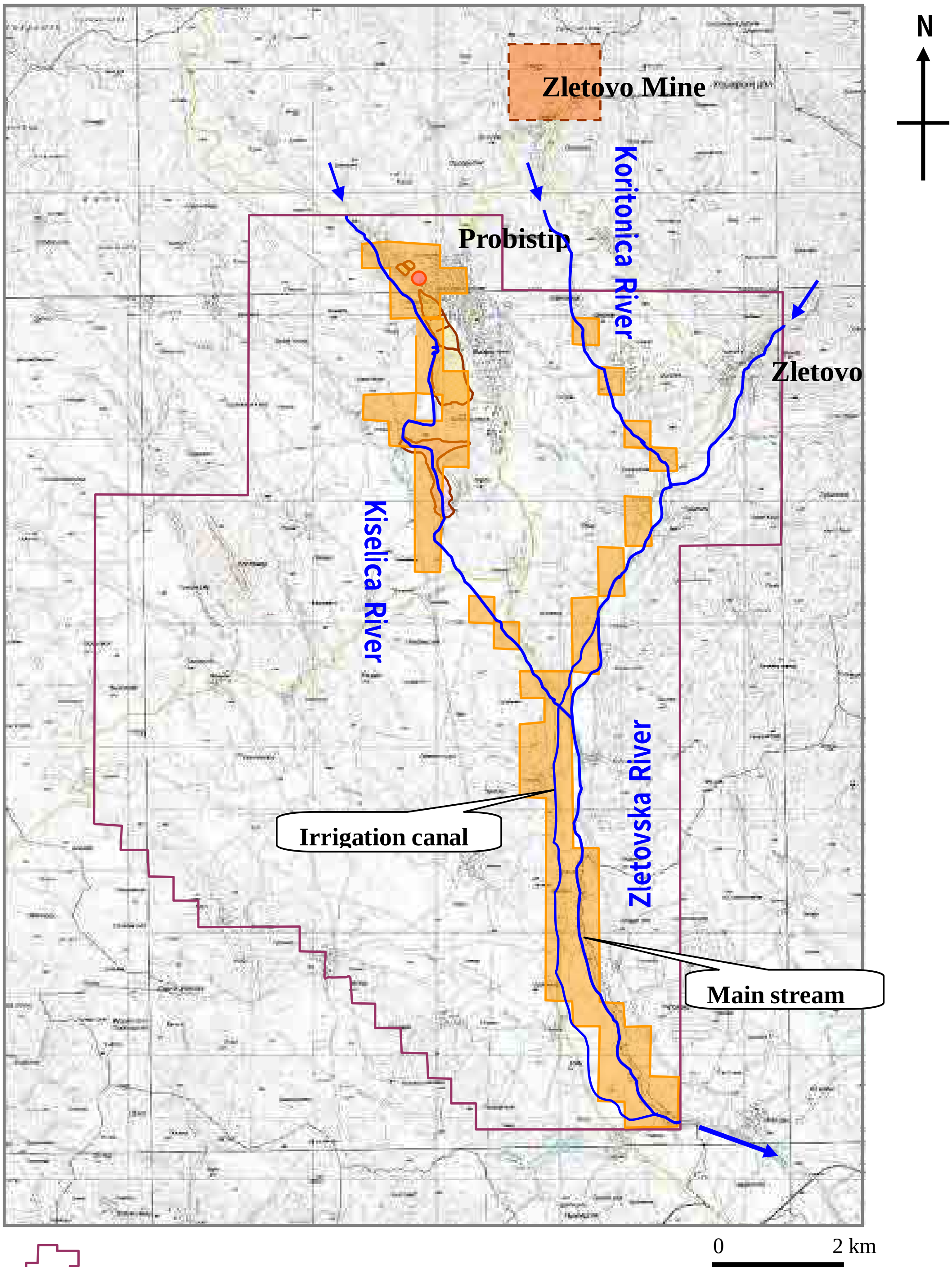
The soil contamination zone along the Zletovska River after the junction of the Kiselica River becomes much wider and longer, because contaminated sediments derived from the Koritnica and Kiselica Rivers are mixed together, especially along the small stream like irrigation canal in parallel with the Zletovska River as shown in Figure 3.2.



400m grid soil survey area and grids

3 High concentration grid (3 means class of high concentration)
(Soil contamination by As-Cd-Cu-Pb-Zn-Mn)

Figure 3.1 Integrated High Concentration Grid Map of Heavy Metals
(Soil contamination by As-Cd-Cu-Pb-Zn-Mn)



400m grid soil survey area
Zletovo mining site
Integrated high concentration grids of As, Cd, cu ,Pb, Zn and Mn (except natural causes)
River
Tailings dam
Processing plant of Zletovo Mine

Figure 3.2 Distribution of Heavy Metals on the Surface in the P/P Area
(Concentration of 400m surface soil, surface water and river bottom sediments)

3.2 Contamination of Surface Water and River Bottom Sediments in the Pilot Project Area

The surface water of Kiselica River is characterized by high concentration of Zn and Mn, especially the uppermost stream (SW-06) of the river (Figure 3.3) is marked by high Pb and Zn concentration and middle stream (SW-05) of the Kiselica river shows also the highest concentration of Zn and Mn, and appears to be affected by the tailings dams.

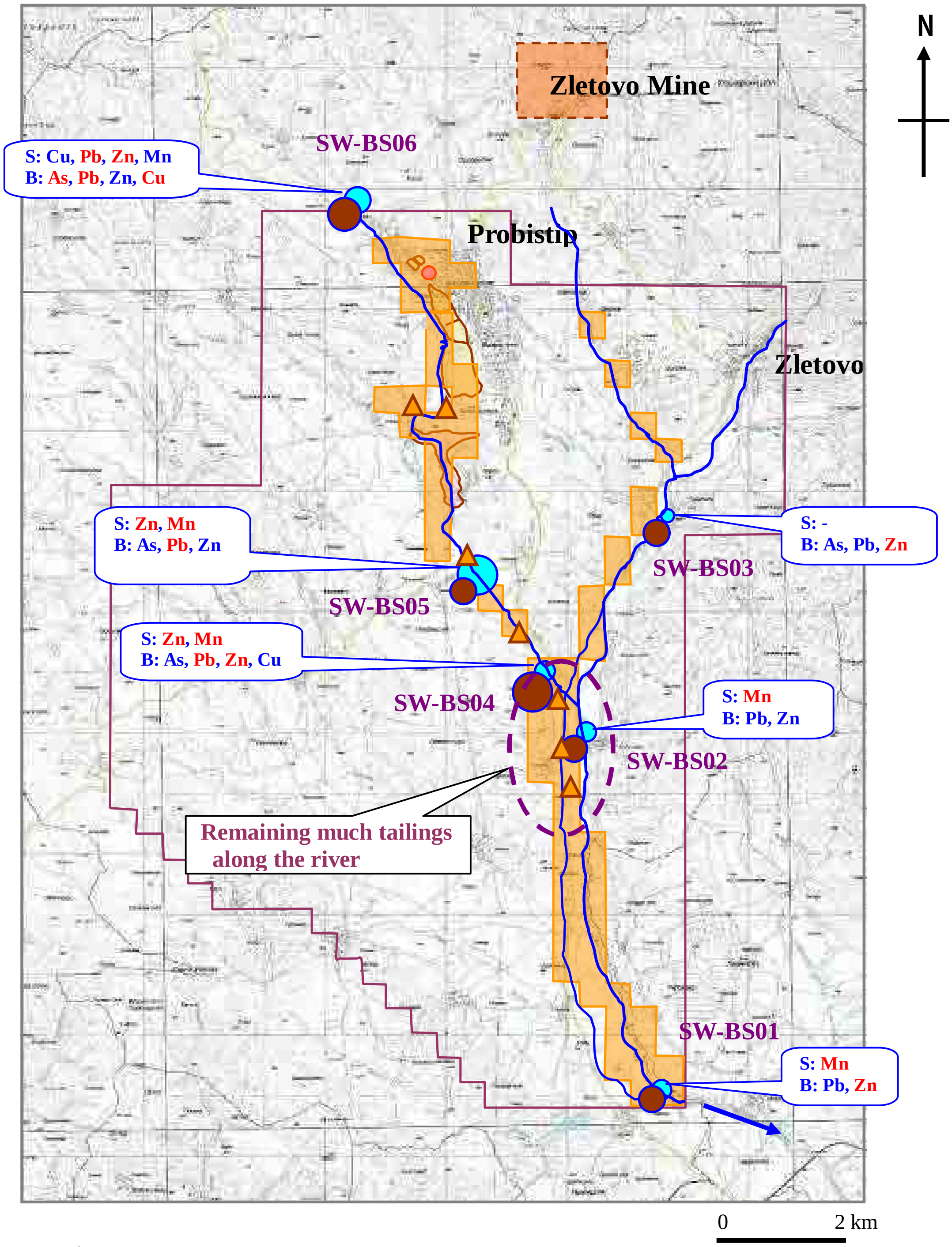
The surface water of the uppermost stream (SW-03) of the Zletovska River is clean, all measured concentrations of heavy metals are less than standards for water quality. However, after junction with the Kiselica River, the concentration of Mn increases and exceeds the standard for water quality, because contaminated water of the Kiselica River flows into the Zletovska River and contaminated water is likely to be eluted from river bottom sediments around the junction of the Kiselica River (Figure 3.3).

On the other hand, the river bottom sediments of all locations in the area contain much Pb, Zn, and As, especially the lower stream of the Kiselica River shows very high content of Pb and Zn. As results of field investigation and drilling survey, tailing materials and/or weathered (oxidised) tailings are widely found in the lower stream of the Kiselica River and western side of middle stream of the Zletovska River. Therefore, much old tailings including also recent tailings are still remaining around the junction of two rivers (Figure 3.3) and show the secondary contamination sources of soil and water.

3.3 Groundwater Contamination in the Pilot Project Area

Most of groundwater along the Kiselica and Zletovska Rivers is contaminated by Zn, Mn and Pb. and the groundwater of MBH-3 (Kiselica River) and 8 (Zletovska River) wells contains Cd exceeding the Water Quality Standard (0.01mg/L). In particular, groundwater contamination at the middle stream of the Zletovska River has a close relation with the remaining old tailings. Therefore, the heavy metals including Zn, Mn, Pb, Cu and Cd are possibly due to elution from the remaining old tailings materials and contaminating to the groundwater as well as surface water.

In addition, the groundwater of MBH-7 well, located at the upper stream of the Kiselica River and west of the New Tailings Dam, contains much Mn and Zn. It is possible that new tailings still continue to flow out from the Old Tailings Dams through the new canal, and contaminated groundwater is also flowing into the downstream (Figure 3.4).



△ Old tailings confirmed by drilling survey, etc.

Integrated high concentration grids of As, Cd, cu ,Pb, Zn and Mn (except natural causes)

Sampling point of surface water (Blue) and river bottom sediments (Brown)

: High concentration of heavy metals presented by size of circle — S: Surface water, B: Bottom sediments

Mn : Very high concentration of heavy metal

Figure 3.3 Distribution of Tailings, Heavy Metals on the Surface in the P/P Area

(Concentration of 400m surface soil, surface water and river bottom sediments)

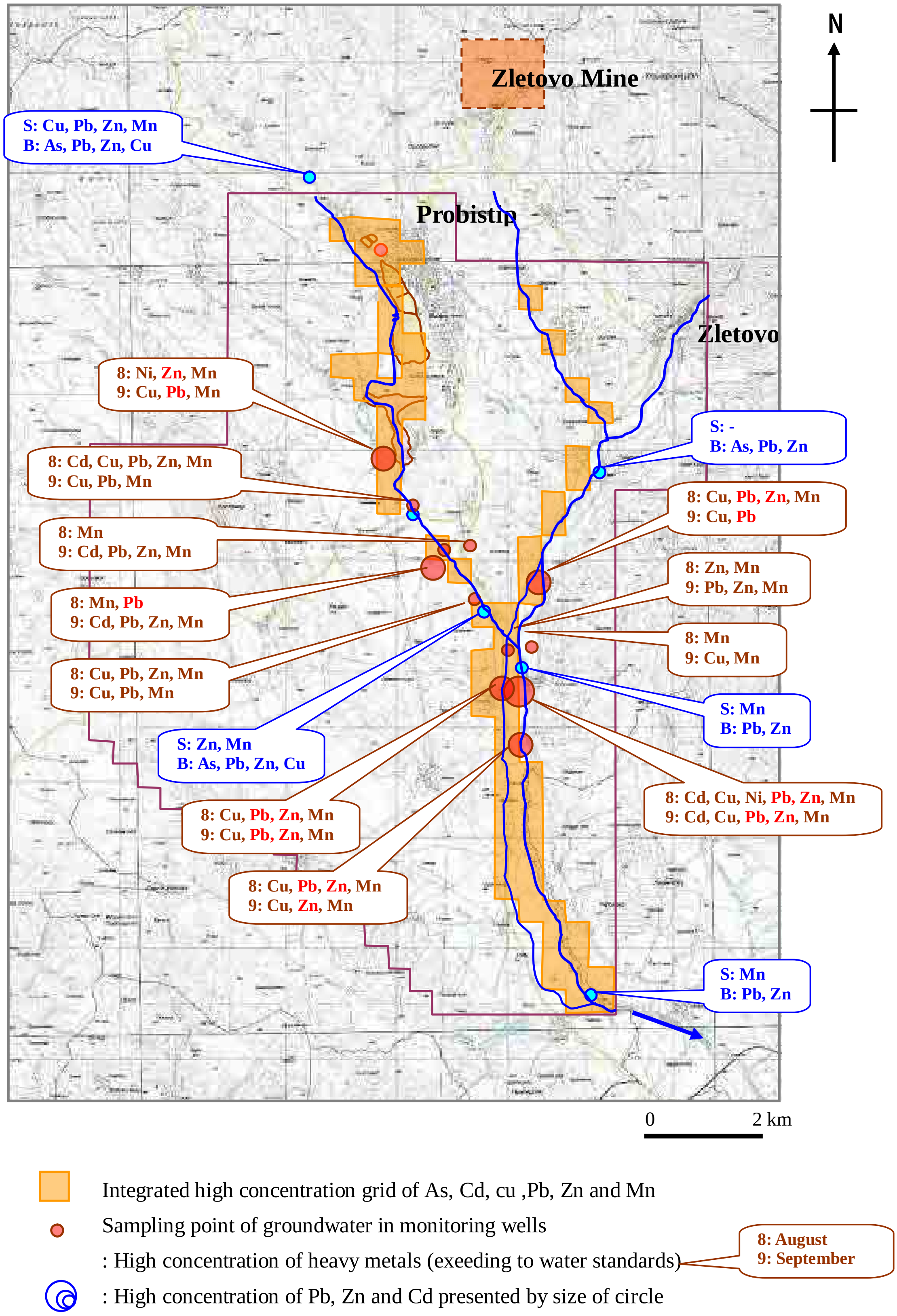


Figure 3.4 Distribution of Heavy Metals in the Groundwater in the P/P Area

(Concentration of 400m surface soil, surface water and river bottom sediments)

The Tailings Dam is one of the sources of contamination. For understanding the effect of dissolving component from the Tailings Dam to surface water and groundwater (monitoring well), the results of the elution analysis of the Tailings samples and heavy metal concentrations of groundwater and surface water were considered.

Based on the results of elution analysis of the Tailings, four components of Cd, Pb, Zn and Mn were selected for the further consideration, since they are the heavy metals characterizing the tailings material with high concentration. Because these four heavy metals show good correlations as shown in Table 3.1, the ratios of Pb/Zn, Zn/Mn and Cd/Mn are used for consideration. Table 3.2 shows Pb/Zn, Zn/Mn and Cd/Mn ratios of the tailings, surface water and groundwater.

Table 3.1 Correlation Coefficients of Elution Values of the Tailings

Correlation Coefficient	Cd	Pb	Zn	Mn
Cd	1			
Pb	0.740	1		
Zn	0.977	0.808	1	
Mn	0.956	0.599	0.914	1

Table 3.2 Pb/Zn, Zn/Mn and Cd/Zn Ratios of the Tailings, Surface Water and Groundwater

Sample No.	Location	Pb/Zn	Zn/Mn	Cd/Zn*100
Old Tailings Core Samples	Upper part of Kiselica R.	0.038	0.17	0.79
New Tailings Core Samples	Middle part of Kiselica R.	0.11	0.04	1.64
SW01	Lower part of Zletovska R.	0.07	0.15	0
SW02	Middle part of Zletovska R.	0.13	0.18	0
SW03	Upper part of Zletovska R.	2.00	0.07	0
SW04	Lower part of Kiselica R.	0.00	0.13	0
SW05	Middle part of Kiselica R.	0.02	0.06	0
SW06	Upper part of Kiselica R.	0.02	0.48	0
MBH01	Upper part of Zletovska R.	0.44	0.20	0.04
MBH02	Upper part of Zletovska R.	1.00	0.11	0.04
MBH03	Middle part of Zletovska R.	0.03	0.26	1.84
MBH04	Middle part of Zletovska R.	0.13	0.02	0.01
MBH05	Middle part of Zletovska R.	0.73	0.84	0.01
MBH06	Lower part of Zletovska R.	0.18	0.88	0.02
MBH07	Upper part of Kiselica R.	0.22	0.02	0.01
MBH08	Upper part of Kiselica R.	0.58	0.11	0.04
MBH09	Middle part of Kiselica R.	1.19	0.02	0.02
MBH10	Middle part of Kiselica R.	0.80	0.05	0.01
MBH11	Middle part of Kiselica R.	0.16	0.21	0.01
MBH12	Lower part of Kiselica R.	1.24	0.21	0.01

* Average values were used for the tailings

The following are the chemical characteristics of elution values of the tailings, surface water and groundwater.

Tailings: The tailings of the Old Tailings Dam show lower Pb/Zn and Cd/Zn and higher Zn/Mn compared with those of the New Tailings Dam. Consequently, the elution values of the Old Tailings Dam show relatively lower Pb and Cd and higher Zn compared with those of the New Tailings.

Surface Water: The surface water of the Zletovska River shows relatively higher Pb/Zn and Zn/Mn, and Cd values are lower than detection limit. The enrichment of Zn at the BS02, located near the mouth of the Kiselica River, can be attributed by the dissolution of Mn from the secondary deposits of the tailings occurring at that location. The surface water of the Kiselica River shows relatively low Pb/Zn. Zn/Mn is relatively high in the upper stream area and becomes lower in the lower stream area. The tendency of the higher Zn and lower Pb in the upper stream area can be explained by dissolution of heavy metals from the Tailings Dams.

Groundwater: The groundwater along the Zletovska River shows higher Pb/Zn in the upper stream area. The groundwater seems to be diluted in the lower stream area. It seems to be enriched in the middle stream area because of dissolution of heavy metals from the secondary deposits of the Tailings. The increase of Zn/Mn toward lower stream with abrupt increase in the middle stream area is attributed by the enrichment of heavy metals by the secondary deposits of tailings. The Cd/Zn is very low along the Zletovska River except very high (1.84) only in the middle stream area. This is also explained by dissolution of heavy metals from the secondary deposits of the Tailings. The groundwater along the Kiselica River shows lower Pb/Zn and Zn/Mn in the upper stream area. The gradual increase of these towards down stream is explained by the addition of heavy metals from secondary deposits of the tailings occurring along the river side. The Cd/Zn is very low in the groundwater along the Kiselica River. It tends to become slightly higher in the middle stream area.

3.4 Soil and Groundwater Contamination Mechanism in the Pilot Project Area

(1) Sources of soil contamination

Sources of soil contamination by heavy metals in the area is definitely derived from mining activities and related mining facilities, etc., and natural causes including mineralisation zone, geological units, etc. The high content of heavy metals caused by nature such as geological features is excluded from the definition of the soil contamination for this study. Therefore, high content of heavy metals including Ni, Co, Cr zone in the southwestern and northwestern parts of the area, Zn and Mn zone in the northeastern part of the area were excluded for further consideration.

Sources of the soil contamination in the area consist of old and new waste dump area of mine sites, processing plant, tailings dams, battery factory, old wastes dump, etc. as shown in Figure 3.5 and Table 3.3.

(Old wastes)

Old waste dumps including mining activities of the Roman age are found in the northern part of the area. There are some old caves with wastes around the present mining site in the northern part of the area. However, the volume of wastes, etc. is unknown. In general, acidic water containing much heavy metals seeps from old wastes. The surface water of SW-06 (Figure 3.5), located uppermost stream in the area, contains high concentration of Cu, Pb, Zn and Mn. This water seems to be affected by seeped water from old wastes.

(New wastes)

New wastes by recent mining activities are being dumped around adits of mine and disposed into the Koritnica river. Numerous fragments and gravels of low grade ore and waste are found along the river, and most of fragments and gravels are coated by black manganese oxide.

(Adits)

Acidic water (pH 2 ~ 4) has been discharged from adits of mine and generally contains much heavy metals, including Pb, Zn, Cd, Cu, Mn, etc. Most of discharged water drains into the Koritnica River as shown in Figure 3.2.

(Processing plant)

The processing plant for crude ore is located in the northern part of Probistip residential area and beside Tailings dam TD-I. There is a transportation route of crude ore, ore dressing equipments, stockyards of crude ore and concentrates, transportation equipments of tailings to dumping sites, etc. in the plant site. Implement of actions to improve environmental management is urged for the mining company.

(Tailings dams)

Tailings dams consist of six dams, namely TD-I, TD-II, TD-III, TD-IV, TD-V (Old Tailings Dams) and New Tailings Dam as shown in Figure 6.2. These dams are intensive contamination sources of soil, water (and groundwater) and air.

(Battery plant)

A part of the Battery plant is still continued to be operated at present. As results of the soil survey, high concentrations of heavy metals were confirmed in and around the plant. Planning and implementation of improved environmental management are necessary.

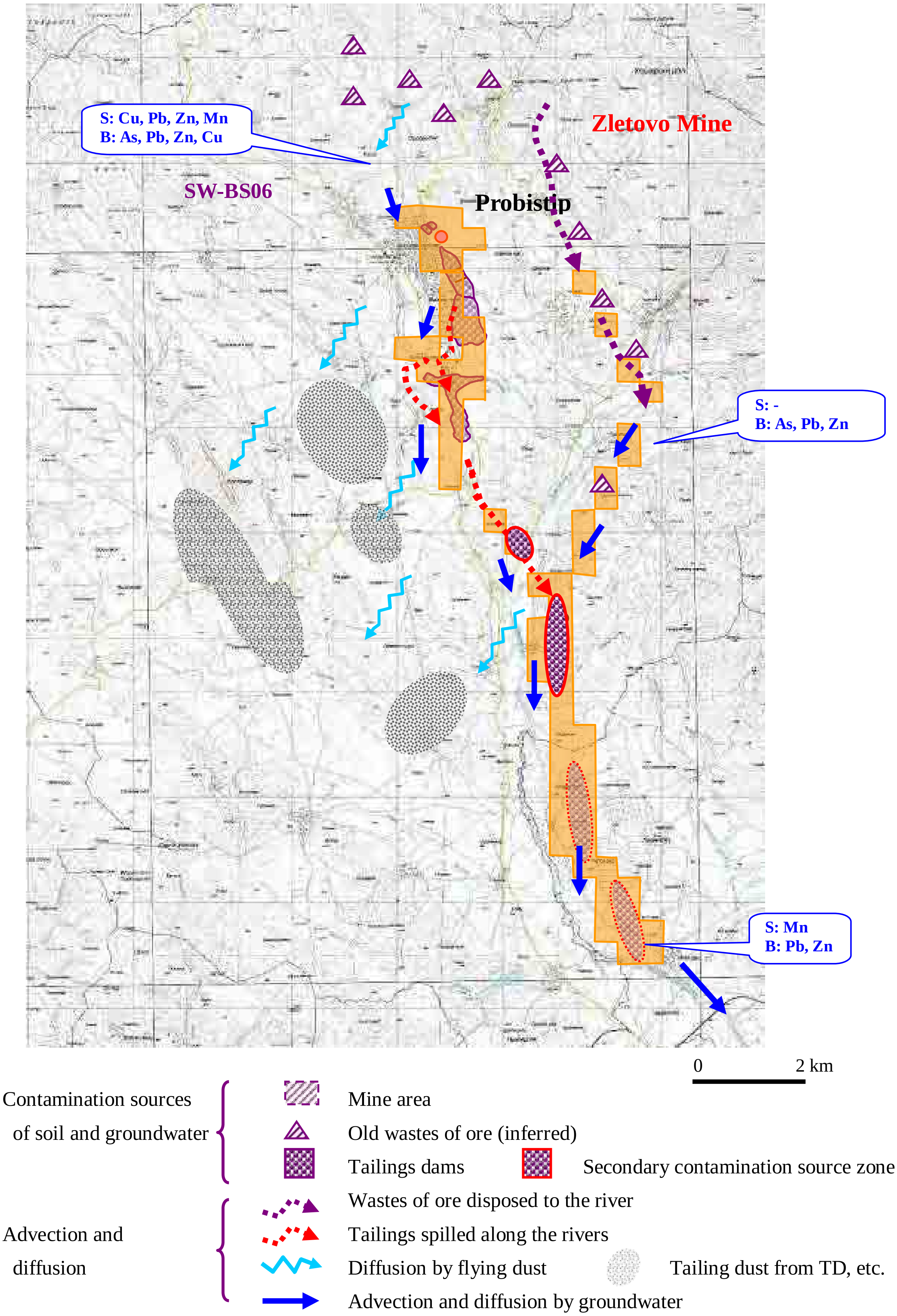


Figure 3.5 Soil and Groundwater Contamination Mechanism in the P/P Area

Table 3.3 Contamination Sources in the P/P Area

Sources of Soil Contamination	Location		Condition	Influence to Soil and Water Contamination
1. Primary Sources	Old mine sites		- Old ore wastes: Roman age, small scale	Acid water to river, caves, dust, etc.
	Mine site (Zletovo Mine)		- Using at present, Pb-Zn sulphide ore, underground mining	Acid water, caves, dust, etc.
	Old Tailings Dams	TD-I	- Soccer pitches, covered by soil and grass - Location in residential area	Acid water with heavy metals, collapse in small scale, dust, etc. (dust: air pollution)
		TD-II	- Sub-station, etc., covered by soil - Location in residential area	Seeped acid water with heavy metals, erosion, collapse of tailings, dust, etc. (dust: air pollution)
		TD-III	- Covered by soil and re-forestation - Location along Kiselica River	Seeped acid water with heavy metals, erosion, collapse of tailings, dust, etc. (dust: air pollution)
		TD-IV	- Bare-ground - Location along Kiselica River	Seeped acid water with heavy metals, erosion of dikes, collapse and spill out of tailings, dust, etc. (dust: air pollution)
		TD-V	- Bare-ground - Location along Kiselica River	Seeped acid water with heavy metals, erosion of dikes, collapse and spill out of tailings, dust, etc. (dust: air pollution)
	New Tailings Dam		- In use at present - Location along old Kiselica River	Drainage of acid water with heavy metals, collapse, spill out of tailings, dust, etc. (dust: air pollution)
	Processing Plant		- In use at present - Location in residential area	Acid water to river, caves, dust, industrial waste, etc.
	New wastes of ore		- Dumping and disposed into River	Acid water to river, caves, dust, etc.
	Battery Plant		- Disposal of wastes	Soil and water contamination
2. Secondary Sources	Lower stream of Kiselica River		- River bottom sediments	Seeped water with heavy metals from tailings, dust, etc.
	Around junction of Kiselica and Zletovska Rivers		- Sediments	Seeped water with heavy metals from tailings, dust, etc.
	Along the Koritnica River		- River bottom sediments	Seeped water with heavy metals from ore wastes, dust, etc.
	Middle stream of Zletovska River after junction with Kiselica River		- Sediments	Seeped water with heavy metals from tailings, dust, etc.
	Lower stream of Zletovska River		- River bottom sediments	Seeped water with heavy metals from ore wastes, dust, etc.

(2) Secondary contamination sources

(Spill incidents of tailings and secondary contamination sources of tailings)

The main collapse of tailings occurred in 1976 and much tailings material was spilled to downstream along the valley of Kiselica and Zletovska Rivers.

There are varying reports regarding the depth of the tailings residues that covered parts of the valley in the days after the collapse, and this would of course depend on the width of the valley. In Tripitanci (located in the valley 8km south of Probistip), the tailings reached in the valley of 2 ~ 3m deep. Further south in Pisica (14km south of Probistip), the depth of tailings was 15cm.

At the bridge over the Kiselica River (in between Buciste and Neokazi), the tailings blocked the channel under the bridge and built up against the bridge, so that the tailings were even pushed across the road. The tailings visibly remained around the bridge for 3 ~ 4 years.

Consequently, in several locations, including areas between the Old and New Tailings Dams, middle stream of the Kiselica River, lowermost stream of the Kiselica River, middle stream of the Zletovska River, and downstream of the Zletovska River, oxidised tailings are confirmed still to remain along the rivers by geological and drilling surveys. These remaining tailings are thought to be secondary contamination sources, because very high concentration of heavy metals of soil are widely found in those areas.

(Secondary contamination sources of sediments along the Koritnica Rive)

Numerous fragments and gravels containing much Pb (galena), Zn (zincblende) and Cu (calcopyrite, etc.) ore and coating by manganese oxide are found in alluvial sediments along the Koritnica River. These sediments are originated from the Zletovo Mine area, partly natural and mostly ore wastes from the mine site.

These sediments are considered to be high potential sources of high concentration of heavy metals in soil. Therefore, it is necessary to enforce strict environmental management.

(3) Soil and water contamination in the area

Stage-1

The primary soil contamination in the area mainly originates from the old and present mine sites (ore waste dump areas), Old and New Tailings Dams and processing plant as shown in Figure 3.5. Most of the contamination sites are located in the northern to central parts of the area, and the components of soil contamination consist of Cd, Cu, Pb, Zn, Mn and As. Although the primary soil contamination occurred in and around the original sites, the contamination of heavy metals were gradually extended to much wider to the area by surface water, groundwater and air dust as shown in Figures 3.6 and 3.7.

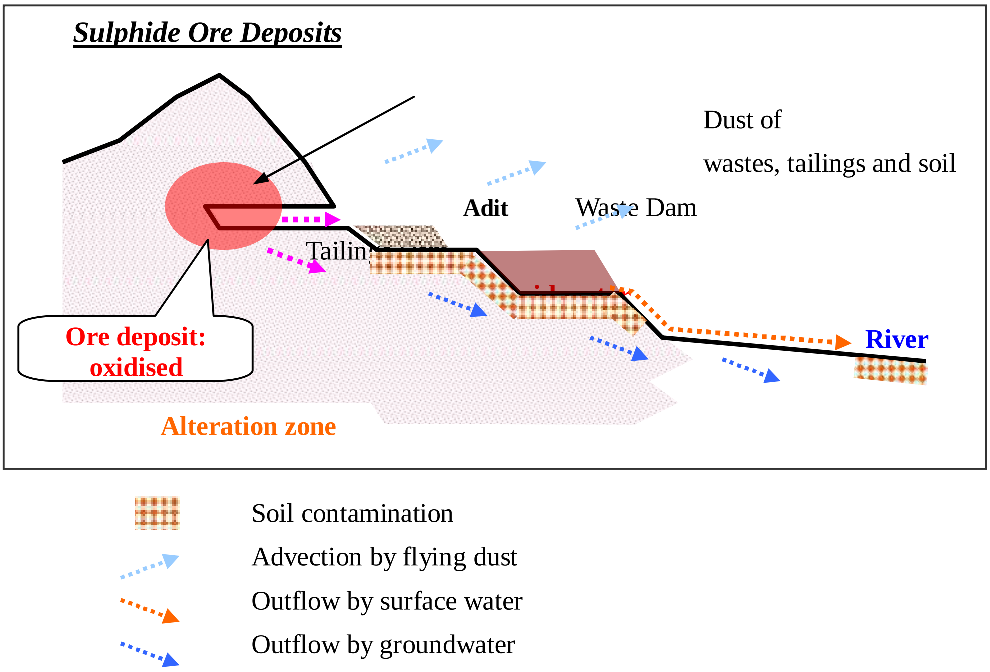


Figure 3.6 Soil Contamination Mechanism in the P/P Area

Stage-2

The main collapse of tailings occurred in 1976 and much tailings material was spilled and widespread to downstream along the valley of the Kiselica and the Zletovska Rivers. After 30 years, in several locations, including the areas between Old and New Tailings Dams, middle stream of the Kiselica River, lowermost stream of the Kiselica River, middle stream of the Zletovska River, and downstream of Zletovska River, much tailings are still remained along the rivers. These remained tailings are secondary contamination sources as shown in Figure 3.5.

In addition, numerous fragments and gravels containing much ores are out flowed from mine site and becomes high potential sources of high concentration of heavy metals in soil as shown in Figure 3.5.

Although the secondary sediments of tailings were emplaced in the middle stream of the rivers, the sediments will migrate slowly to the downstream depending on the strength of the river flow (especially flooding).

Stage-3

After the soil contamination by spill incident of the Old Tailings Dam, contamination by tailings was widely extended to the downstream in the area, the primary and secondary soil contamination gradually migrated to the downstream and diffused to the surroundings of the rivers.

Much tailings dusts flown from the Old and New Tailings Dams have been diffused around the tailings dams, and a part of tailings dusts is likely to have reached to the southwestern and southern agricultural lands in the area by southwestwards wind (Figures 3.6 and 3.7). As a result of migration of tailings dusts, the soil and groundwater contamination have occurred after emplacement of the dust in the sites, and it was followed by crops contamination in the sites.

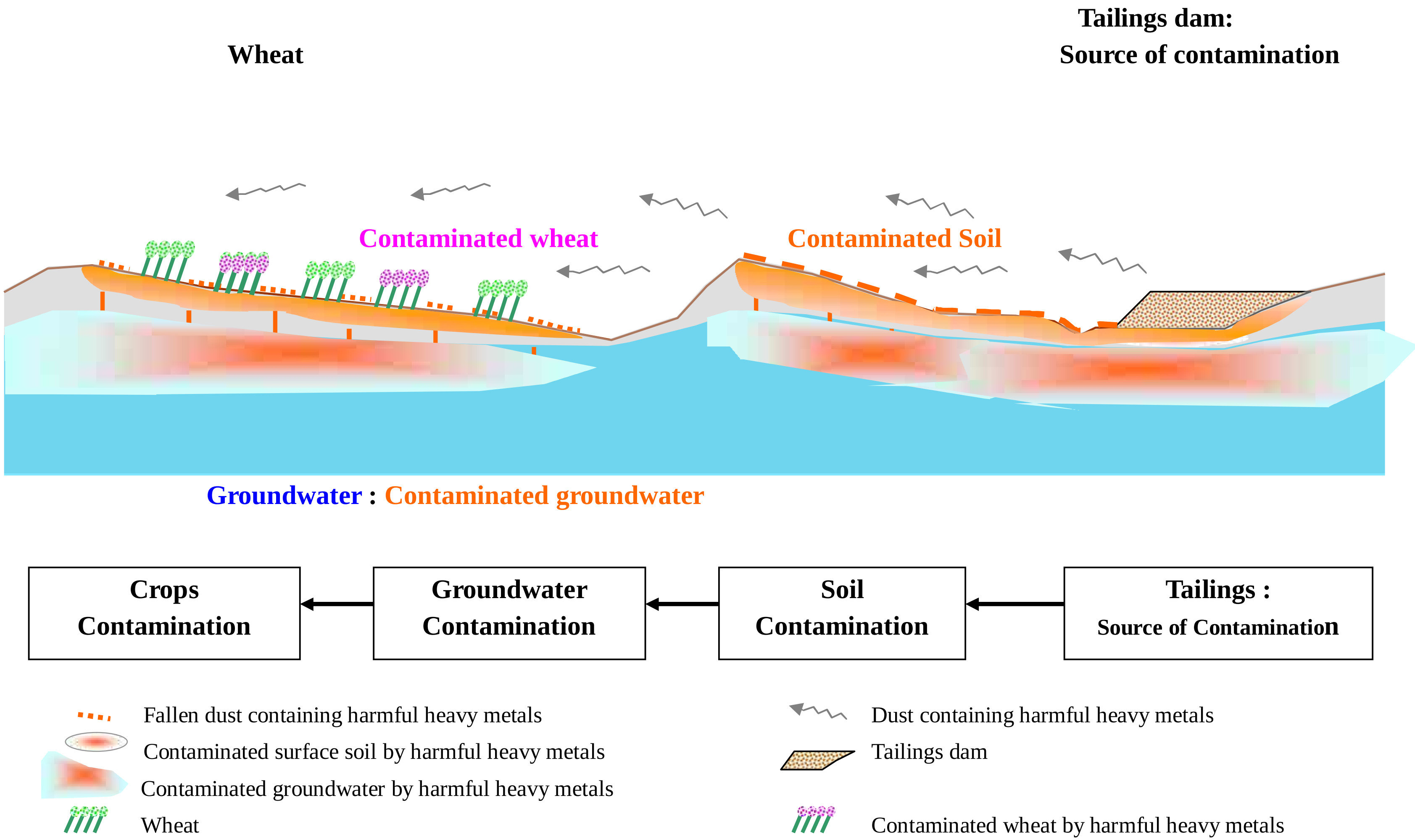


Figure 3.7 Schematic of Soil Contamination Mechanism among Soil, Groundwater and Crops in the P/P Area