Moving down or not?

PHASE II: Yara

Water supply related technical support for the in-situ adaptation of Yara to the water crisis

February 2014

KAM FOR SUD

The second phase of the project "Moving down or not?" was undertaken by

Kam For Sud (KFS)

Swiss NGO working for a sustainable development in Nepal since 1998, www.kamforsud.org

comprises the report at hand, as well as a second report concerning Dheye, was written by Daniel Bernet, Marco Baumer, Fidel Devkota and revised by Silvia Lafranchi Pittet who are briefly introduced hereafter:

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- In-field project coordination, hydrology and hydraulic related aspects, editing the report.

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- Responsible for all geology and hydro-geology related issues.

Fidel Devkota: Visual Anthropologist and postgraduate at the Freie University Berlin, Germany; Scientific advisor of the French association Du Bessin Au Nepal; Many years of first-hand practical field work experience in Dheye;

- Responsible for all social and cultural aspects of the project.

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- Overall coordination of the projects, review and revision of the report.

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Summary

The first phase of the project "Moving down or not?", initiated by Kam For Sud, elaborated the best adaptation strategy for the three heavily water-stressed villages Samzong, Yara and Dheye, all located in Upper Mustang, Nepal. The study highlighted several technical key questions, which had to be left unanswered within the limited scope of the project's first phase, posing major obstacles for the communities to proceed with the implementation of the recommended strategies. For that matter, Kam For Sud undertook the project's second phase, aimed at providing the missing technical expertise, concluding in two self-standing reports: one about Dheye and one, the report at hand, concerning Yara. The initially planned technical investigations regarding Samzong's relocation had to be abandoned, as the reconstruction of the village, locally supported by the Lo Mustang Foundation, was suddenly initiated at a location exposed to hydro-geological risks, unlike the one assessed in the project's first phase. Therefore, the field work had to be focused on raising awareness about the associated hazards. As of January 2014, this effort has proven to be fruitful, as the new village is going to be reconstructed at the initially identified, safe location.

Concerning Yara, the project's first phase highlighted an increasing water stress in the future. In order to cope with this challenge, the need to reduce the water demand (e.g. diversifying economic activities, altering cultivation methods, switching to less water demanding crops etc.) along with improving the water supply (e.g. reducing water losses, switching to alternative irrigation methods etc.) was identified. For the successful adaptation in the long run, a conjunctive implementation of both strategies is paramount. However, measures to reduce the demand need to be developed together with the community and implemented step-wise for positive long-term effects. Improvements of the water supply, on the other hand, are suitable to mitigate the water stress instantly.

As currently all the water from the river is abstracted, more water can only be made available by improving the water efficiency. Although, this may lead to higher irrigation intensities and consequently to enhanced infiltration rates further accelerating soil deformations, this measure is a crucial part of the adaptation process. Therefore, the project's second phase focused on the elaboration of measures aimed at enhancing the highly inefficient irrigation water supply system in order to contribute to the successful in-situ adaptation of Yara.

The irrigation system, comprised of an open, earthen channel, whereof few short sections are piped, is subjected to large local and continuous water losses. To reduce these losses, the main channel is proposed to be turned into a buried pipeline over the whole length of more than two kilometers. The abstraction is recommended to be built with removable pipes, mobile enough to be adapted to the changing riverbed. Inspection chambers, distributed at regular intervals, will ensure that important maintenance tasks can be carried out. Distribution chambers will connect the pipeline to the open channel network supplying the water to each individual field. The five currently used gully crossings, one of which needs urgent repair, will be used to transport the water to the village's far side.

Spellings

Many different spellings of places, water bodies and names can be found in Upper Mustang. This is mainly due to the fact, that many names were translated from the local languages into Nepali and/or English. In the report at hand the spellings from the documentation of the project's first phase are adopted and are consistently used hereafter. This section lists other common spellings.

Dheye	Dhe, Dhey, Dhye, Dewa
Samzong	Sam Dzong, Samdzong

Glossary

Bhote Pipal	Himalayan Poplar tree
Differential settlings	Unevenly distributed, small-scale, downwards movements of the ground
Gabion	Blank-wired cage, filled with stacked rocks, used for slope stabilizations, flood and erosion protection etc.

Abbreviations and acronyms

FAI	Fondation Assistance Internationale
HDPE	High-Density Polyethylene
KFS	Kam For Sud
LMF	Lo Mustang Foundation
MS	Mild Steel
NGO	Non-Governmental Organization
NPO	Non-Profit Organization
NPR	Nepalese Rupees
OD	Outer Diameter
PVC	Polyvinyl Chlorid
RCC	Reinforced Cement Concrete
SUPSI	University of Applied Science of Southern Switzerland

Acknowledgments

One of Kam For Sud's main principles concerning all undertaken projects is to achieve a sustainable impact. Consequently, it was clear that Kam For Sud would try to continue the support for the three heavily water-stressed villages in Upper Mustang, after the conclusion of the project's first phase. Despite realistic hopes for a further funding, the donor decided to withdraw, not willing to fund the proposed second phase aiming at providing crucial technical support for the villages. Therefore, different other possibilities to fund the project were elaborated.

Kam For Sud is very grateful that after all, the project could be financed with a few very generous donations, namely from Bruno Häfliger, Laura Aboli and the Jacob foundation. Furthermore, Marco Baumer, part of the expert team, offered to contribute his expertise as a volunteer. Moreover, Fidel Devkota, who is concluding his PhD, agreed – on virtually shortest possible notice – to complete the expert team as a volunteer, as well. Kam For Sud would like to express its gratitude for these contributions, without which the project could not have been realized.

Preface

In order to lead the reader comprehensibly through the report at hand, it is structured as follows: First, the scope and objectives of the project's second phase are elaborated (Chapter 1). After discussing geological aspects (Chapter 2), the current Irrigation water supply system is described and the enhancement thereof is elaborated (Chapter 3). A short outlook concludes the main part of this report (Chapter 4). Supplementary, this report provides design propositions (Appendix A), as well as the specific locations of the proposed units (Appendix B, C and D).

1 Introduction

It is hard to believe that "(…) until around the sixteenth century, most of Lo/Mustang had an abundance of water from the surrounding snow-covered mountains, diverse vegetation, and dense forest from which Lo-pa people built monumental structures, (…)" (Dhungel 2002) when trekking through Upper Mustang nowadays. In fact, hydrological conditions have been changing severely (Bernet et al. 2012a). In the course, numerous settlements in Upper Mustang, the northern part of the Mustang District in Nepal, which consists of a north-south oriented valley opening up to the Himalayan plateau in the north (Figure 1.1), have been subjected to heavy water stress in addition to several other issues such as geological risks, overall weakening the livelihoods of the concerned communities.

Figure 1.1: Map of Nepal, bordering China in the north and India in the east, south and west. The red ellipse highlights the location of Mustang District. North direction is ↑, the map was taken from Zurick et al. (2006).

In order to understand the drivers and consequences of these processes, as well as to elaborate an appropriate adaptation strategy for the three particularly affected villages Samzong, Yara and Dheye an applied study financed by the Fondation Assistance Internationale (FAI) was undertaken in 2012 by the NGO Kam For Sud (KFS) jointly with the University of Applied Science of Southern Switzerland (SUPSI) in collaboration with the local NPO Lo Mustang Foundation (LMF). The outcome[1] of the holistic study, hereafter referred to as Phase I, was

[1] The study's results are presented in four reports including a synthesis report in addition to one report for each village (Bernet et al. 2012a). Note that the report at hand builds up on this study. Please refer to these reports for background information and for that matter either to the synthesis report (Part I) or the report concerning Yara (Part III). They can be downloaded from Kam For Sud's website (www.kamforsud.org).

the recommendation of a specific adaptation strategy for each village. For two out of the three studied villages a resettlement of the whole village was proposed.

Within the limited scope of Phase I the suggested adaptation strategies could not be elaborated in a way to investigate and resolve all issues in detail. In particular, some technical key questions had to be left open which pose a major obstacle for the communities to proceed with the implementation of the recommended measures. Since the current conditions are pushing the communities to take immediate action, suboptimal decisions might be made.

Therefore, KFS initiated the second phase of the project "Moving down or not?", hereafter referred to as Phase II, and assembled an interdisciplinary expert team once more to provide missing technical expertise in order to advance the successful adaptation process. The project's written output includes two self-standing reports: one about Dheye and one, the report at hand, concerning Yara.

The initially planned technical investigations concerning Samzong's relocation had to be abandoned, as shortly before the field work started, it became apparent that the reconstruction of the village, supported by the Lo Mustang Foundation (LMF), the local partner of the project's first phase, was initiated at a different location than the one assessed in Phase I. As this location is an unsuitable place for the future village, mainly because it is exposed to hydro-geological risks, KFS's field work had to be focused on raising awareness about the associated hazards of the changed resettlement plan. This effort has proven to be fruitful, as the new village is going to be rebuilt at the safe location investigated in Phase I, as of January 2014.

1.1 Background

To embed the report at hand into the right context, as well as to elaborate the scope and objectives, background information is provided in the following sections.

1.1.1 Review of Phase I

In Phase I, the water supply system in Yara was studied and documented in detail[2]. It was concluded that the water stress in Yara would even increase in the future. In order to cope with this challenge, the need to reduce the water demand (demand management) along with improving the supply (supply management) was identified (Bernet et al. 2012b). Demand management measures include diversifying economic activities, altering the way crops are cultivated or switching to less water demanding crops altogether. Supply management, on the other hand, encompasses measures increasing the supply, such as reducing water losses, allotting additional water sources and switching to alternative irrigation methods.

[2] For background information, please refer to Bernet et al. (2012b), which can be downloaded from Kam For Sud's website (www.kamforsud.org).

It was suggested that the first step to improve the situation in Yara should consist in realizing non-constructive measures. Though their potential could not be quantified in Phase I, they were believed to increase water use efficiency considerably. Furthermore, the community could implement such measures independently from external financial support. Such an engagement by the community was believed to be important, as it would demonstrate a positive attitude towards own contributions.

Above all, a simple non-constructive intervention was proposed in Phase I, as described in the following. Traditionally, the irrigation system is at each landowner's free disposal for one whole day in turns, which are determined by lottery anew each spring. The fields of all landowners are not concentrated in a particular zone but are dispersed within Yara's agricultural area. Irrigating the fields, which are located far apart, is consequently associated with a high amount of water losses. The traditional irrigation scheme was recommended to be altered, by dividing the total field area into different zones. Each day, a particular zone would be irrigated. In this way, the water would be brought to the fields more efficiently, since local and constant losses occurring during the process of routing water to fields, distributed over the whole agricultural area, would largely be circumvented.

1.1.2 Social and cultural aspects

The before mentioned non-constructive measure was introduced and discussed with the community during Phase I. It was planned to further promote such measures during Phase II. However, the field work in the project's second phase highlighted social and cultural conflicts, which were not apparent before.

Discussions with the community in September 2013, roughly one year after the first phase's field work, revealed that, although the benefits of altering the irrigation scheme were well understood by the community, the measure was perceived to be infeasible. Reportedly, no trial was started because of the following two main concerns of the community:

- Disputes and clashes between the landowners would be inevitable
- There would not be enough specialized laborers available for this arrangement

As these concerns only seem partly justified, especially given the looming circumstances, the community was expected to develop solutions, propositions or at least ideas about how to solve the water loss caused by the traditional irrigation scheme. However, the community seemed to be rather passive, hoping for outsiders providing a one-fits-all solution. This attitude might be attributed somewhat to past engagements of several organizations, announcing the implementation of unrealistic measures, which were obviously never realized.

Without doubt, a successful adaptation strategy for Yara involves altering certain traditions. The elaborations above highlight that such transformations need time, effort and do not simply happen, even if the situation is seemingly urgent. Possible measures have to be discussed, elaborated and implemented together with the community step-wise. Thus, the need for a long-term collaboration becomes apparent.

1.2 Scope and objectives

The limited time and resources of Phase II required constraining the extent of the study. Namely, the focus of Phase II concerning Yara lies on the elaboration and presentation of the enhancement of the main irrigation water supply channel, which was found to be highly inefficient.

However, it is important to understand that the elaborated supply management measures are only part of the whole adaptation strategy. Reducing the losses of the irrigation water supply system alone might relieve the water stress, but is not solving the problem in the long run. The in-situ adaptation of Yara to the water crisis is only possible through socially and culturally sensitive application of demand and supply management measures that should be addressed in an implementation phase (Phase III).

1.3 Resources

The report at hand is based on the following resources:

- Study “Moving down or not?” (Bernet et al. 2012a)
- Field work of Daniel Bernet, Marco Baumer and Fidel Devkota, accompanied by Tsering Gurung in the fall 2013
- Satellite imagery provided by Google Earth Pro
- Literature (cited separately; see Bibliography in Chapter 5)

2 Geological aspects

As elaborated in Phase I and confirmed in Phase II, Yara's main geological issue is the prevalent instability, expressing itself in a series of cracks in the upper consolidated sediments, which consist of fine conglomerates with a mudstone matrix. This unfavorable geological setting has several implications, as elaborated in the following sections.

2.1 Infiltrating water

It is quite evident that infiltrating irrigation water is one of the triggering elements of these instabilities. On ridge below the cultivated fields water emerges along an almost continuous line, corresponding approximately to the depth of the cracks found in the upper part of the settlement.

Enhancing the water supply, which results ultimately in more available water in the fields, might therefore have adverse effects regarding geological soil stability. The risk is that, due to the higher amount of available water, the fields are irrigated more intensely, leading to enhanced infiltration reaching the slide surface, overall increasing the velocity of the soil's movements.

Therefore, the sole enhancement of the irrigation water supply system is not recommended, although it is a necessary measure for the successful adaption of Yara to the water crisis. Increasing the water supply efficiency has to go in hand with demand management measures aimed at improving the agricultural yield while the water input is reduced, resulting in less infiltration and, thus, reduced geological instabilities.

2.2 Erosion mitigation measures

The Puyung Khola as well as water accumulated during storm events within the numerous gorges in and around Yara cause erosion and destabilize the slopes. For that matter, gabions were installed at several places. However, they were mostly not installed properly. Namely, they were merely set on the surface, without putting them at least partly underground. As mentioned in relation to the broken gully crossing (Appendix A.5), it is very important that, before gabions are placed, the sites are excavated adequately. As elaborated in Phase I, the main trench dividing the village in two parts, is subjected to erosion at several places within the village. At these locations, properly placed gabions should be installed.

3 Irrigation water supply

The irrigation water supply channel is very inefficient. Only part of the water, abstracted from the Puyung Khola, is reaching the fields. Along the channel, which is simply dug into the soil, a lot of water is lost by percolation (continuous losses) and leaks (local losses). In the following sections, a plan to reduce water losses and thus increase the irrigation water supply's efficiency is outlined.

3.1 Current situation

The irrigation water supply system consists of an open channel, whereof few short sections are piped (Figure 3.1). To cross five different-sized gullies different structures were built. Shortly before the field work in Yara at the end of September 2013, the largest of these crossings collapsed (orange arrow, Figure 3.1) and needs repair (Appendix A.5).

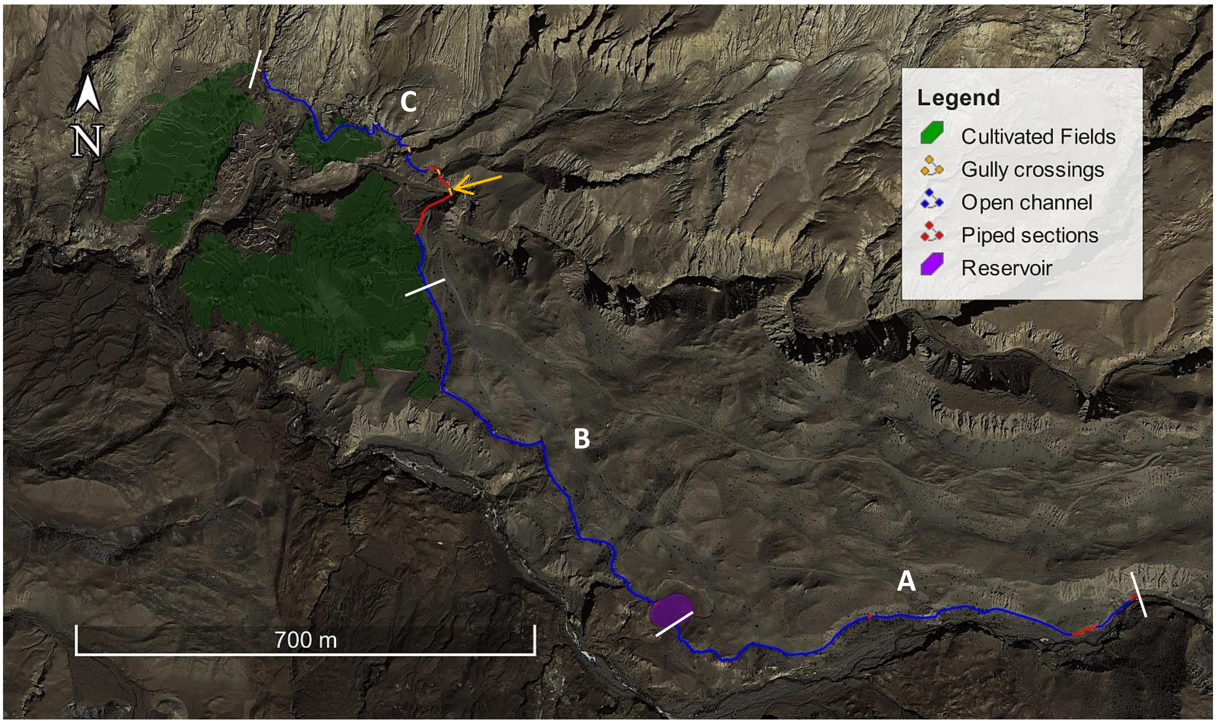

Figure 3.1: Current irrigation water supply system. The water is abstracted from the Puyung Khola, brought to the reservoir and distributed by obstructing the open channel at certain places to direct the water to the desired fields. The system is structured into three legs delineated by the white lines, namely the abstraction (A) and, related to the trench dividing the village, the distribution channel to the village's left (B) and the right side (C). The orange arrow highlights the inactivated gorge crossing (source: Google Earth Pro, accessed 28/01/2014).

3.2 Enhancement plan

To decrease the continuous water losses along the main channel, the open channel is proposed to be replaced by a High-Density Polyethylene (HDPE) pipeline. To decrease the local losses, small concrete chambers accommodating proper diversion mechanisms are proposed at strategic points allowing the efficient diversion of water from the main pipeline to the fields. Moreover, recommendations how to fix the inactivated gorge crossing (Appendix A.5) are provided. The salient features of the proposed pipeline are summarized in Table 3.1.

Table 3.1: Summary of the pipeline's salient features. As a reference, the costs of the buried pipes are indicated. Note that these costs do neither include transportation nor installation of the pipes.

Description	Unit	Value
Number of intake structures	(-)	1
Number of inspection chambers	(-)	4
Number of distribution chambers	(-)	3
Number of gully crossings	(-)	5
Number of outlet structures	(-)	1
Length of flexible abstraction	*(m)*	62
Length of section A (160 mm OD)[a]	*(m)*	730
Length of section B and C (180 mm OD)[b]	*(m)*	1'404
Pipeline's total length (section A, B and C)	*(m)*	2'134
Pipe costs (section A, B and C)	*(NPR)*	3'161'446.90

[a] 1'258.43 NPR/m (160 mm OD, 6 kg force/cm^2) according to Panchakanya's pricelist (Appendix E.1)
[b] 1'598.00 NPR/m (180 mm OD, 6 kg force/cm^2) according to Panchakanya's pricelist (Appendix E.1)

Note that for the pipeline's design no hydraulic calculations were carried out. The necessary height differences could not be assessed within the scope of the study at hand. Therefore, the currently used pipes (Section 3.1) are taken as a reference. The largest pipes in leg A (Figure 3.1) have an outer diameter (OD) of 160 mm. Reportedly, the capacity of these pipes are suitable to convey all the water, which can be abstracted from the Puyung Khola. Consequently, the pipeline transporting water to the reservoir is recommended to be built with 160 mm (OD) pipes. From the reservoir downstream, pipes with a larger diameter, namely 180 mm (OD), are suggested, as all the water accumulating during the night needs to be distributed within daylight. The dimensions of chambers and flush systems etc. are estimated in relation to the proposed pipes, without hydraulic calculations. Prior to implementation, a leveling along the pipeline's axis, or at least measurements of characteristic points, should be undertaken, to be able to optimize the system hydraulically.

3.2.1 Abstraction

The Puyung Khola exhibits eroding tendencies (Figure 3.2) posing a major challenge regarding the abstraction of the water. Building rigid structures into the dynamic river is not recommended. Due to high flow conditions and floods during the monsoon season, rigid structures are easily damaged or even washed away. Therefore, a flexible solution, adaptable to the changing riverbed, is required.

Figure 3.2: There are indications that Puyung Khola's riverbed is eroding. The yellow arrows highlight characteristic points which can be identified easily in both pictures. The orange arrows indicate a large rock (left), which fell into the riverbed (right), as the riverbank underneath was eroded. ***Left:*** *The abstraction as of May 2012 (photo: 11/05/2012, Daniel Bernet).* ***Right:*** *Sixteen months later, the abstracted water (red arrow) is clearly situated at a higher level relative to the flowing water in the Puyung Khola (black arrow). The proposed safe location for the pipeline's intake structure is indicated by a white arrow (photo: 26/09/2013, Daniel Bernet).*

Roughly thirty meters downstream of the place depicted in Figure 3.2, the valley opens up slightly. The right riverbank is not directly exposed to possible erosion from uphill and can be protected from erosion caused by the Puyung Khola. Upstream, the valley becomes narrower and the slopes on both sides are instable and geologically active (Figure 3.3). Therefore, the intake structure, connecting the pipeline's first leg with the mobile water abstraction, is suggested to be located at the location highlighted in Figure 3.2 (right, white arrow).

The flexible abstraction, which needs to be roughly sixty meters long, as of September 2013, is suggested to be designed with light, flexible, removable pipes. For instance, two parallel Polyvinyl Chlorid (PVC) pipelines, often used in drainage systems, each with an outer diameter (OD) of 110 mm (4"), might be installed. These pipes are light, can be joined dryly for the given purpose and consequently, can also be removed quickly in the case of need. Namely, if the river's water level is high, the pipes should be removed to prevent them from being flushed away. After the flood, they can be reinstalled.

Figure 3.3: Just before the field work of Phase I, a landslide barred the Puyung Khola, roughly hundred meters upstream of the current water abstraction. A small pond was formed and the water was flowing over the deposited bar (yellow arrow). At the depicted site, as well as further upstream, the slopes on each side of the valley are unstable and geologically active. Building any rigid structure in this environment is not recommended (photo: 11/05/2012, Daniel Bernet).

In case the erosion of the riverbed will have progressed to such a level that a long flexible pipe is required to bring the water to the main intake structure (Section 3.2.2), an additional buried pipeline leg will be necessary upstream of the intake. The new leg should be buried and the corresponding valley side consolidated. Another chamber will be required for the transition from the flexible abstraction to the additional buried pipeline leg.

Overall, the flexible design of the water abstraction ensures that the system can be adapted to the changing riverbed continuously, which is crucial for a well-functioning system in the long term. However, the flexibility of this method, especially the need to remove the pipes before a flood, highlights the necessity of a caretaker responsible for the operation and maintenance of the pipeline (Section 3.2.6).

3.2.2 Leg A

The flexible abstraction (Section 3.2.1 and Figure 3.4) transports the water from the river to the intake structure. From there, the water is conveyed to the reservoir in a buried pipeline. Three small inspection chambers are foreseen to ensure smooth operation and to promote easier maintenance and repair work.

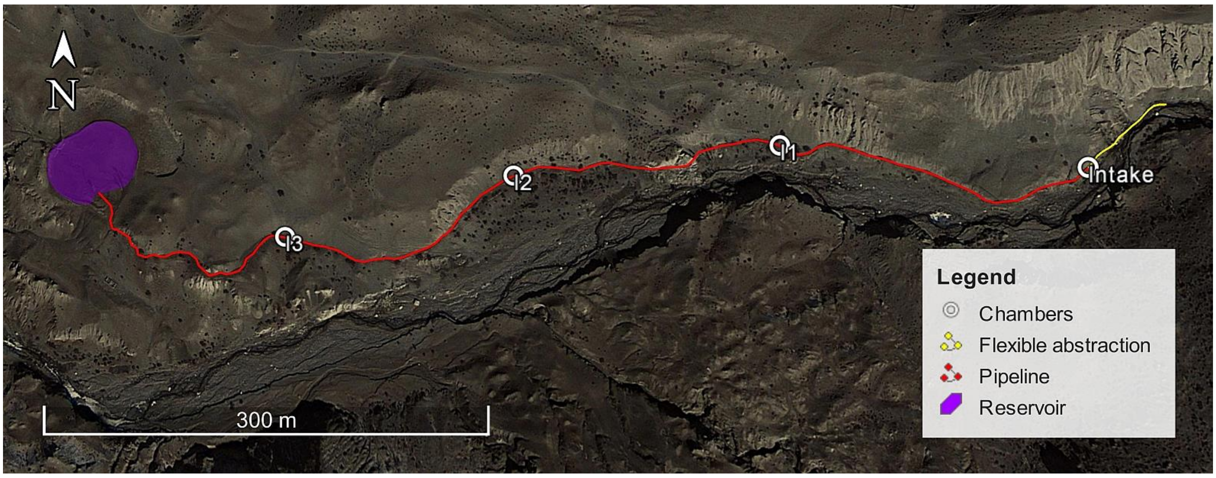

Figure 3.4: Leg A of the planned irrigation water supply pipeline. The water is abstracted from the river with flexible pipes (yellow line) and conveyed to the intake chamber. From the intake structure, the water is transported to the reservoir through a buried pipeline. Along the pipeline, three inspection chambers (I1 – I3) are foreseen (source: Google Earth Pro, accessed 28/01/2014).

Intake structure

The intake chamber collects the water abstracted by flexible pipes. Before the abstracted water enters the pipeline, it has to be rid of its transported gravel and floating debris. Thus, the chamber has to accommodate the following features:

- Gravel trap, to rid the abstracted water from gravel
- Flush, to extract the settled gravel from the chamber
- Trash rack, to prevent coarse matter to enter the pipeline
- Overflow, to direct the abstracted water back to the river

As mentioned before, Yara and its surroundings are situated on a huge landslide (Bernet et al. 2012b). Consequently, the whole area is subjected to movements and differential settlings. It is therefore necessary that the whole structure is solid enough to withstand such movements of the ground without cracking and collapsing. Both the pipeline and the abstraction are flexible enough to compensate movement of the intake structure to a certain degree. It is therefore recommended to build the structure with Reinforced Cement Concrete (RCC) or with solid masonry work and thick plastering. Furthermore, the structure has to be covered and the walls need to be higher than ground level to prevent surface flow and debris from entering. An exemplary design of the structure, including estimated dimensions, is presented in Appendix A.1.

Pipeline

In addition to differential settlings, storms create surface flow, heavily eroding places with an abrupt change of gradient. Such a gradient is created by open channels which are perpendicular to the slope line and are therefore particularly exposed. Therefore, a HDPE pipeline is proposed, as these pipes are flexible enough to compensate differential settlings without collapsing and can be buried in order to prevent a change in gradient. Another reason speaking in favor of burying the pipeline is the fact that HDPE degenerates when exposed to sunlight. In addition, installing the pipes underground has the favorable side-effect that expansion and contraction is heavily reduced, as the pipes are exposed to much smaller temperature differences.

Damages caused by suddenly breaking pipes leading to water flowing out under pressure, could not only be observed in Yara itself, but in Upper Mustang in general. Such events can trigger deep erosion cuts and lead to the complete interruption of the pipeline. To prevent such damages, the pipeline should be embedded with sand in a trench that is at least one meter deep, as described in Appendix A.2. Overall, carefully installing and embedding the pipeline underground is paramount for a long-lasting, reliable system. In addition, the need to instantly repair any leaks has to be stressed and, thus, demands a well-functioning repair and maintenance concept (Section 3.2.6).

As mentioned before, the pipes currently in use (Section 3.1) are taken as a reference, since their flow capacities have proven to be suitable to convey all the water abstracted from the Puyung Khola. Thus, a diameter of 160 mm (OD) is recommended for leg A of the irrigation water supply pipeline.

Inspection chambers

Regular inspection chambers ensure a smooth operation of the supply system. In case the pipeline fails, the problem can be located quite easily. The inspection chambers have to accommodate the following features:

- Flush, to empty the chamber for maintenance and repair
- Trash rack, to prevent coarse matter to enter the pipeline
- Overflow, to direct the abstracted water back to the river

Similar to the intake structure, the inspection chambers need to be covered, the walls need to be higher than the ground level and the whole structure is recommended to be built with RCC or solid masonry work and thick plastering. An exemplary design is presented in Appendix A.3 and the locations of the chambers are specified in Appendix B.1.

3.2.3 Leg B

Whenever the fields need to be irrigated, the outlet of the reservoir, which is continuously fed by Puyung Khola's water, is closed in order to store the water during the night. In the morning the outlet is opened and the water is brought towards the fields through another buried pipeline. To irrigate the fields located on the village's left side, one of the two distribution chambers of leg B has to be activated (Figure 3.5). When irrigating the village's right side, the water flows through leg B undisturbed and is directed to the corresponding fields by leg C's distribution chambers (Section 3.2.4). An inspection chamber is located downstream of the reservoir to ensure smooth operation in addition to the possibility to discard the water safely through an attached long flush pipe.

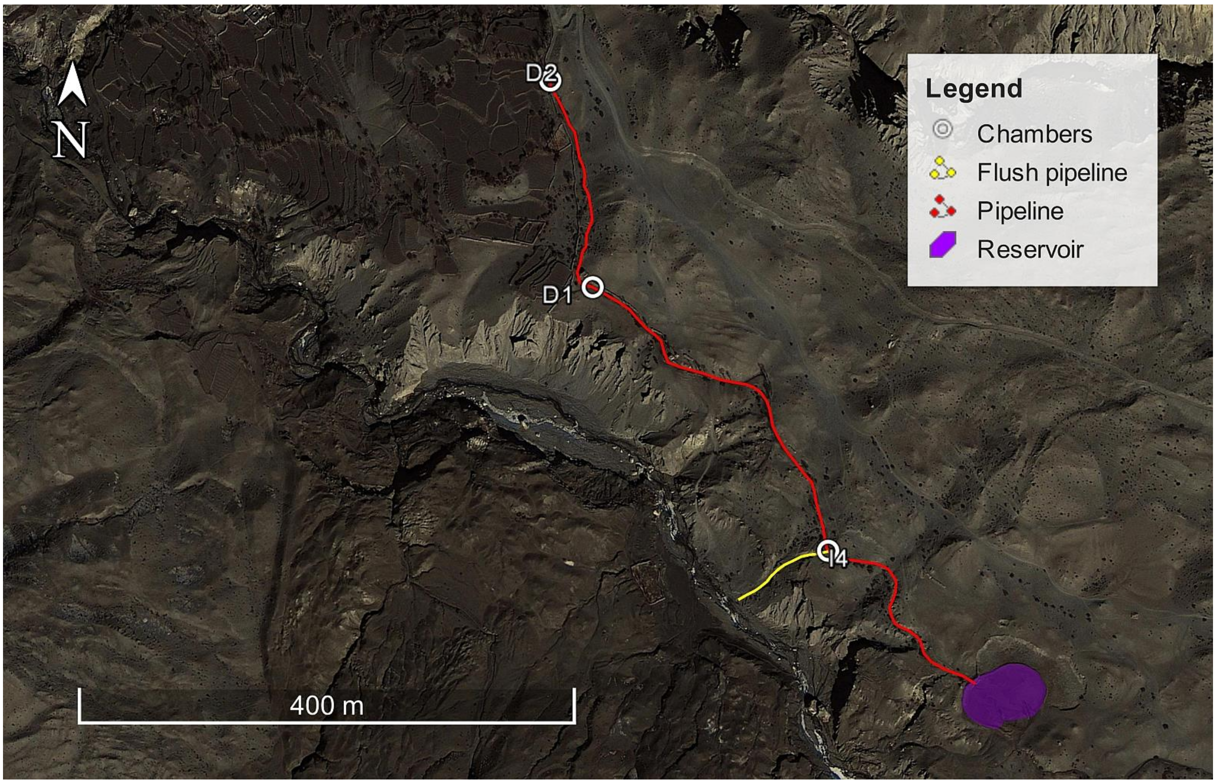

Figure 3.5: leg B of the planned irrigation water supply pipeline. The ponded water from the reservoir flows through a buried pipeline towards the fields. Along the pipeline, one inspection chamber (I4) and two distribution chambers (D1 and D2) are foreseen (source: Google Earth Pro, accessed 30/01/2014).

Reservoir outlet

Currently, the reservoir is operated by inserting and removing a ball of cloth into the short outlet pipe. As a long pipeline is planned to be connected to the outlet, the cloth could easily be stuck and plug the pipeline completely. Additionally, the current outlet is not watertight and the manipulations are not convenient. For that matter, a pipe gate is strongly recommended. Ideally, the pipe gate cannot be closed and opened quickly, in order to reduce thereby caused pressure surges.

Pipeline

As described in Section 3.2.2, an underground HDPE pipeline is well-suited for the given purpose. For a long-lasting, reliable pipeline it is paramount that it is carefully installed and embedded, as discussed in Appendix A.2.

As mentioned before, the pipeline's first leg transporting water from the Puyung Khola to the reservoir has a recommended diameter of 160 mm (OD). As this pipeline's leg is continuously operated, the following legs, only used during the day, should have a larger flow capacity. Given the facts that, apparently, the maximal abstraction rates were less than the 160 mm pipes' full flow capacity, and the 180 mm pipes downstream of the reservoir proved to be suitable for their purpose, pipes with a diameter of 180 mm (OD) are recommended for leg B.

Inspection chamber

Generally, it is suggested that the abstraction is inactivated, whenever no water is needed within the village for a longer period. However, it may be useful to direct the water back to the river just for a short time, for which a removal of the flexible abstraction pipes is inconvenient. Currently, this is practiced by diverting the water through a gorge just downstream of the reservoir. Unfortunately, this technique led to significant backward erosion endangering the channel and the future pipeline (Figure 3.6). For that matter, an inspection chamber, combining the advantage of such a unit in general and the possibility to accommodate a flush discharging the water safely back to the river without causing adverse effects, is proposed. An exemplary design is presented in Appendix A.3 and the location of the chamber as well as the flush pipeline's routing are specified in Appendix C.

Figure 3.6: Diverting the water from the main channel (orange arrow) into a steep gorge (yellow arrow) draining into the Puyung Khola visibly led to serious backward erosion. This ongoing process has to be stopped immediately, as it is endangering the stability of the current channel and the future pipeline. Therefore, an inspection chamber accommodating a pipeline, safely conveying water back to the Puyung Khola, is proposed (photo: 11/05/2012, Daniel Bernet).

Distribution chambers

To divert the water from the main pipeline to the fields, a slight variation of the inspection chamber, namely the possibility to open and close the pipeline downstream, is envisaged. By closing the chamber's outlet downstream and removing the standpipe at the same time, the water flows out through the bottom of the chamber and is directed to the currently used network of small open channels, which ensures that the water can be brought to each individual field.

Two distribution chambers (D1 and D2) are sufficient to supply all fields situated on the village's left with water. An exemplary design of the distribution chamber presented in Appendix A.4 and the locations of the chambers are specified in Appendix C.2.

3.2.4 Leg C

The last leg of the irrigation water supply pipeline, connected to the distribution chamber D2 (Section 3.2.3), brings water to the village's right side, where the water is distributed to the fields with one distribution chamber and one outlet structure (Figure 3.7). To reach that side of the village, several gullies have to be crossed (Section 3.1 and Appendix D). Five different-sized crossings are in place, whereof one needs intense repair (Appendix A.5).

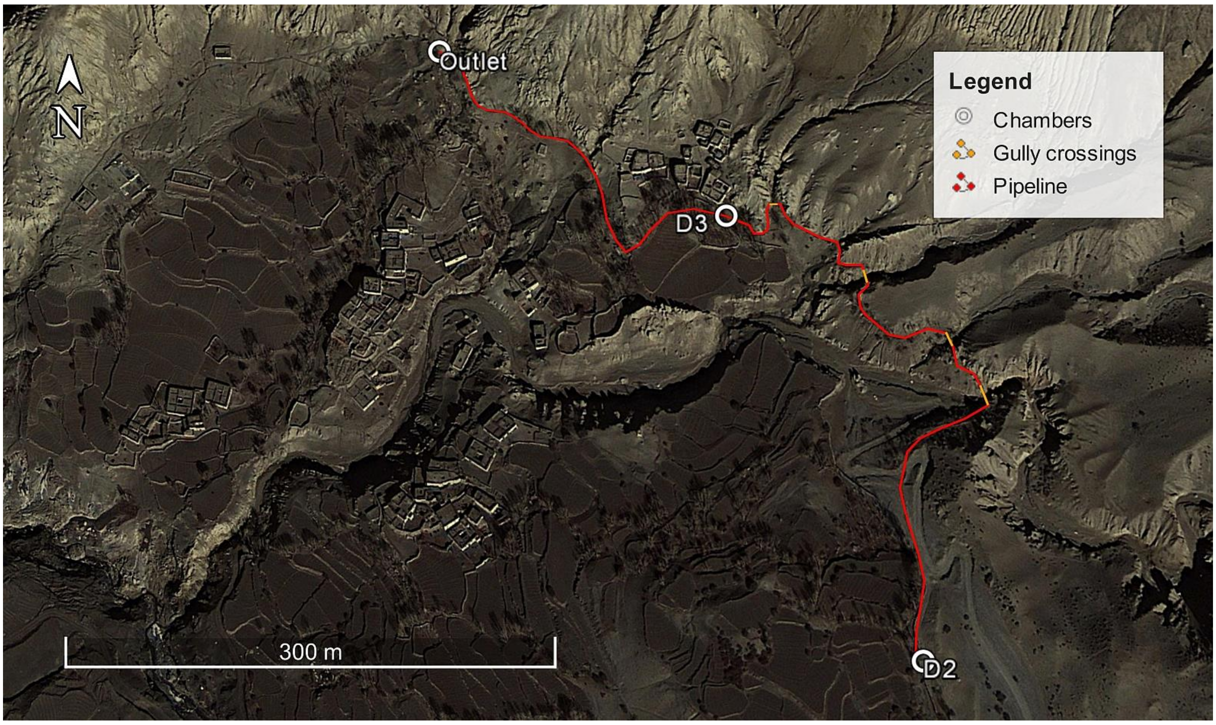

Figure 3.7: Leg C of the planned irrigation water supply pipeline. From the distribution chamber D2, where leg B (Section 3.2.3) ends, the water is brought to the village's right side through several suspended gorge crossings. With the chambers D3 and the pipeline's outlet, all corresponding fields can be irrigated (source: Google Earth Pro, accessed 30/01/2014).

Pipeline

The characteristics (Section 3.2.3), the installation method (Appendix A.2) and the proposed pipe diameter of 180 mm (OD) are the same as in leg B.

Gully crossings

To cross several gullies, different structure types are currently in place. The shortest two crossings (C4 and C5, Figure 7.18 and Figure 7.19, respectively, Appendix D) are composed of a wooden bar supporting pipes or directly conveying the water. It is proposed to install the future pipeline in the same manner.

On either side of one crossing (C2), terraced gabion structures were installed, on which pipes, supported by two wooden sticks (Figure 7.16 in Appendix D), are fixed. Since the whole pipeline might collapse in case the wooden sticks break, a more solid wooden or even iron frame is recommended.

At the two remaining crossings (C1 and C3, Figure 7.15 and Figure 7.17, respectively, Appendix D), solid concrete anchors, on which a steel rope is fixed, was installed to provide means to attach pipes. Unfortunately, the blank wire used to attach the pipeline is generally not strong enough to bear the weight of the pipes, especially when they are filled with running water. Although, the blank wires seem to hold the pipeline at the crossing C3, they did not at the crossing C1. For that matter, a wooden bar was installed resting on stacked rocks on each side of the gully (Figure 7.15, Appendix D). Recently, the base of the structure on the gully's right side was eroded and the whole construction collapsed. To reactivate this crossing, the pipeline is recommended to be fixed on the steel rope. For that matter, thin steel ropes with appropriate clamps are required, as specified in detail in Appendix A.5. Note that the blank wire, currently holding the pipeline of the crossing C3, should also be replaced by these steel ropes and clamps.

Distribution chambers

To distribute the water to the respective fields, one distribution chamber (D3) and the pipeline's outlet are sufficient. The characteristics (Section 3.2.3) and the design (Appendix A.4) of the distribution chamber are the same as in leg B. The location of the chamber is specified in Appendix D.2.

Outlet

The outlet structure is suggested to be designed as a short masonry or cemented open channel section. The main purpose of this structure is to ensure that the water flowing out of the pipeline's end is slowed down and cannot cause erosion and scour. The location of the outlet is specified in Appendix D.3.

3.2.5 Trees along the open channel

At several locations along the open channel, Bhote Pipal were planted, which are used as timber for construction works. These trees are nurtured by water percolating through the earthen channel walls. Although this is a convenient side-effect, it does not justify the channel's inefficiency. Since installing a pipeline will cut off their water supply, the trees are suggested to be moved to an orchard, which can be efficiently irrigated according to the trees' demands.

3.2.6 Operation and maintenance

One of the major short-comings of the current irrigation water supply channel is that nobody is responsible for the operation and, above all, maintenance of the system. This leads to the adverse effects that leaks are not fixed in time, necessary consolidations and reconditioning tasks are procrastinated, which overall leaves the whole system in a bad state.

In the light of making the system more efficient, it is paramount that an operation and maintenance plan is introduced. It is therefore strongly suggested, that a community member is designated to look after the supply system. The caretaker could be paid by the land owners for the work, as they are directly profiting from a well-functioning irrigation water supply system.

The designated person should be trained to do the necessary tasks. Smaller repair works and reconditioning tasks could be done by the caretaker himself, while the caretaker should plan, organize and oversee larger tasks requiring more workforces. Overall, the operation and maintenance plan ensures a well-functioning, reliable system, while looming damages are recognized and fixed, before it is too late.

4 Outlook

Although it may seem that increasing the water efficiency has only advantages, it is important to remember that this is not true in Yara's case. As discussed, higher water availability may lead to increased infiltration rates, and, as a consequence thereof, to accelerated geological soil deformations.

Overall, it is therefore paramount that the proposed enhancement of the irrigation water supply is not implemented alone, but is just a part of a whole well-studied concept. Undoubtedly, the successful adaption of Yara to the water crisis has to include a whole set of well-balanced measures aimed at reducing the water demand, while using the water resources more efficiently.

In Phase I, the first step to improve the current situation in Yara was suggested to consist in realizing non-constructive measures, such as altering irrigation schemes and patterns, to mitigate the water stress, as mentioned before. In Phase II, it became apparent that such socially and culturally sensitive interventions take time and require interactional collaborations. This highlight the need of Yara for long-term support aimed at adapting the community to the changing circumstances, particularly considering social and cultural aspects.

As per February 2014, Kam For Sud plans to take this role and accompany Yara in this transformational process, namely with the third phase of the project "Moving down or not?" (Phase III). It is planned to support the community to elaborate suitable, socially and culturally sensitive measures, aimed at mitigating the water shortage in Yara. These measures include both demand and supply management measures.

5 Bibliography

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6 List of tables

7 List of figures

A Design propositions

Exemplary designs for the main units are described in the following sections. The general design might have to be adapted for each particular unit according to the site conditions.

A.1 Intake structure

The structure has to be covered and the walls need to be higher than ground level to prevent surface flow and debris from entering. At the upstream end of the structure, the chamber's bottom is sloped 1:2, at the other end 1:1. Overall, the bottom slightly drops towards the flush & overflow, which has to be at the lowest point of the chamber (Figure 7.1).

The combined flush & overflow consists of a fixed bottom outlet and a removable stand pipe. The top of the bottom outlet is slightly bigger in diameter than the stand pipe, so that the latter, basically a plug, can be inserted easily. As long as the plug is inserted into the bottom outlet, it acts like an overflow. Whenever the inflowing water exceeds the capacity of the pipeline, for instance in case the pipeline is blocked, the water ponds in the chamber and flows out through the plug once the water table in the chamber is higher than the maximal water depth. Pulling out the plug turns the overflow into a flush, whereby all the ponded water in the chamber is flushed out along with the settled particles.

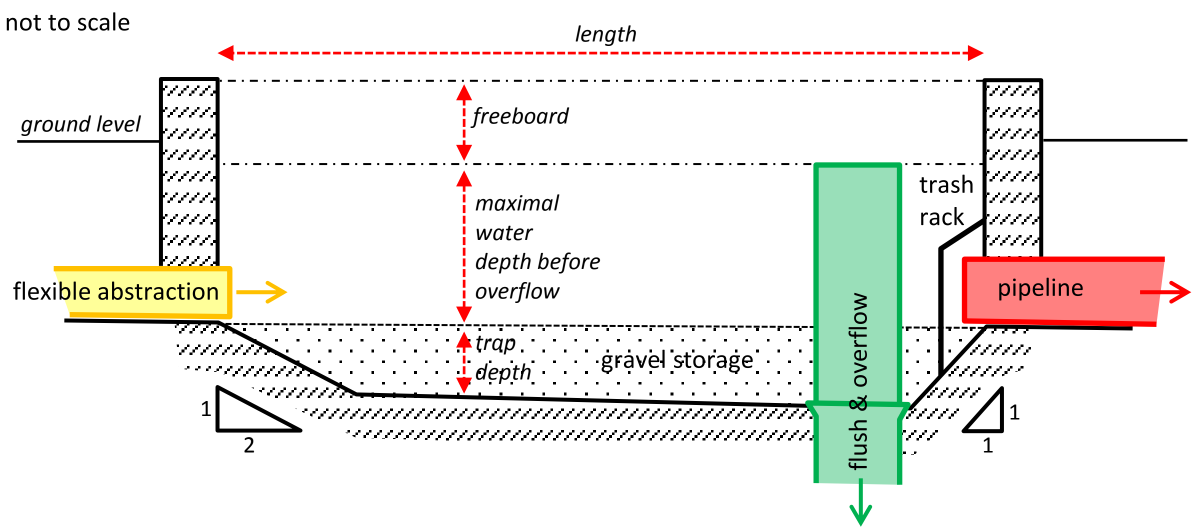


Figure 7.1: Schematic longitudinal section of the intake chamber accommodating the abstraction's outflow, the inlet of the pipeline, a vertical trash rack as well as a combined flush & overflow (drawing not to scale, adopted from Practical Action).

The diameter of the flush & overflow should be larger than the pipeline's and should be suited to convey more water than can be abstracted from the river to ensure that water cannot overflow uncontrollably. Furthermore, the flush & overflow pipe has to transport the water safely back to the riverbed without causing erosion downhill. This is particularly important, as erosion might destabilize the whole slope and even lead to the collapse of the structure and with it, the whole pipeline.

Hydraulically, the water within the chamber should not flow faster than 0.6 m/s in order to remove particles larger than 2 mm (Practical Action). With the coarse dimensions presented in Table 7.1, the flow velocities within the chamber are expected to be well below 0.6 m/s and thus, even smaller particles might settle down.

Table 7.1: Rough estimate of the intake structure's dimensions. The values might have to be adjusted according to the site conditions.

Description	Unit	Value
Width of chamber	*(m)*	1.00
Length of chamber	*(m)*	2.00
Minimal trap depth	*(m)*	0.30
Maximal water depth[a]	*(m)*	0.80
Freeboard	*(m)*	0.40
Flexible pipe's diameter[b] (OD)	*(m)*	0.11
Pipeline's diameter (OD)	*(m)*	0.16
Flush & overflow's diameter (OD)	*(m)*	0.20

[a] It is expected that within the pipeline free surface flow is predominant, as the amount of abstracted water is likely to be well below the pipeline's flow capacity. However, if more water is abstracted, the pipeline's inlet should be allowed to be immersed in order to guarantee proper pressure flow. This ensures that no air is sucked in, which could lead to unfavorable, unstable flow conditions including pressure surges and reduced flow capacities. Therefore, the maximal level before water starts to overflow, relative to the crest of the pipeline's inlet, is recommended to be at least 0.6 m.

[b] As mentioned in Section 3.2.1, two parallel 110 mm (OD) pipes are recommended.

A.2 Pipeline

The pipe's strength is recommended to be 6 kg force/cm^2 (Appendix E.1) in order to withstand pressures and tensions, in particular associated with the expected differential settlings.

Sharp 90° bends should be completely avoided, if possible, as they have proven to be very weak. Instead, bends should be built by hand, which is feasible, as HDPE pipes are quite flexible. However, curves must not have a radius smaller than fifty times the pipe's diameter to prevent the pipeline from damage (Practical Action). For a 160 mm (OD) pipe, the curve's radius must consequently not be below 8 m.

Overall, carefully installing and embedding the pipeline underground is paramount for a long-lasting, reliable system. The general idea how to install the pipeline is illustrated in Figure 7.2.

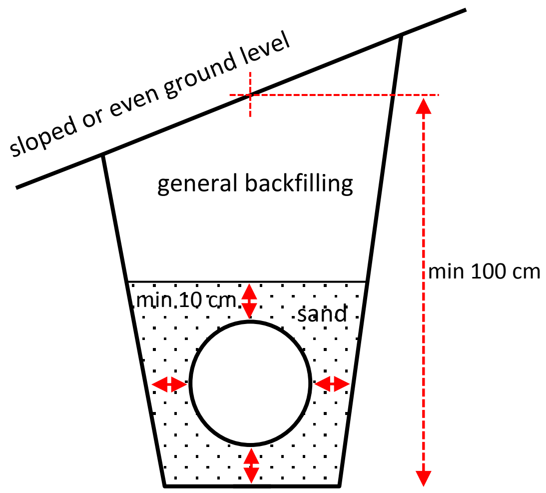


Figure 7.2: The pipeline should be installed with care. The trench should be at least one meter deep. The pipe itself should be embedded by a layer of sand which should be at least ten centimeters thick. Therefore, for a 16 cm pipe (OD), the trench should be at least roughly 40 cm wide at the bottom. The sand embedment shall be covered by general backfilling. The backfilling should be done stepwise. After adding a layer of roughly 20 cm the layer should be compacted well before the next layer is added.

A.3 Inspection chambers

The structure has to be covered and the walls need to be higher than ground level to prevent surface flow and debris from entering. Overall, the bottom slightly drops towards the flush & overflow, which has to be at the lowest point of the chamber (Figure 7.3). Unlike the inlet structure, the inspection chambers do not require gravel storage, as the particles are already removed by the former unit.

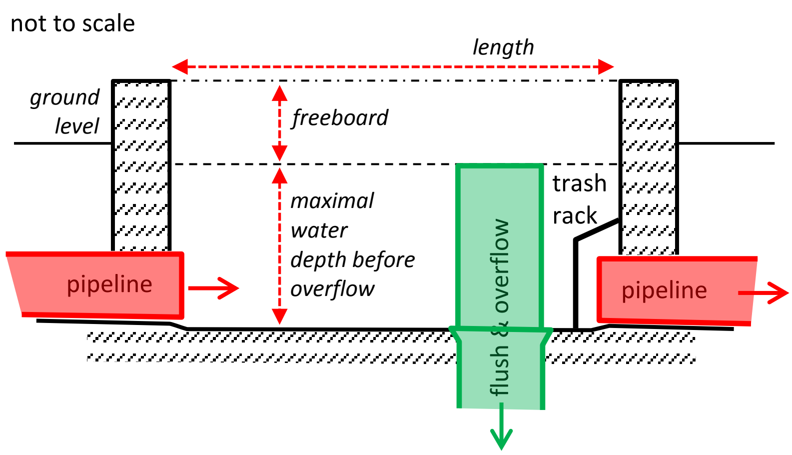


Figure 7.3: Schematic longitudinal section of a inspection chamber accommodating the incoming and outgoing pipeline, a vertical trash rack as well as a combined flush & overflow (drawing not to scale).

The combined flush & overflow consists of a fixed bottom outlet (flush), slightly larger in diameter at the top to allow inserting a removable stand pipe (overflow). In normal operation the stand pipe acting as a plug is inserted into the bottom outlet. Water is allowed to pond in order to allow proper pressure flow under corresponding circumstances. Once the water table in the chamber is higher than the maximal water depth, water starts overflowing into the stand pipe and out through the bottom outlet. Removing the plug turns the overflow into a flush, whereby all the ponded water in the chamber is flushed out.

The diameter of the flush & overflow should be larger than the one of the pipeline to ensure that water cannot overflow uncontrollably. Most importantly, the flush & overflow pipe has to transport the water safely back to the riverbed without causing erosion downhill, as otherwise the structure, and with it the whole pipeline, might collapse.

Recommended approximate dimensions of a typical inspection chamber are presented in Table 7.1.

Table 7.2: Rough estimate of the inspection chamber's dimension. The values might have to be adjusted according to the site conditions.

Description	Unit	Value
Width of chamber	*(m)*	1.00
Length of chamber	*(m)*	1.00
Maximal water depth[a]	*(m)*	0.80
Freeboard	*(m)*	0.30
Pipeline's diameter (OD)	*(m)*	0.16
Flush & overflow's diameter (OD)	*(m)*	0.20

[a] As discussed in Table 7.1, a minimal height difference between the pipeline's crest and the overflow's standpipe is recommended, resulting in a maximal water depth of 0.8 m, before water is overflowing via flush & overflow.

A.4 Distribution chambers

The chamber has to be covered and the walls need to be higher than ground level to prevent surface flow and debris from entering. Unlike the inspection chamber (Appendix A.3), it has to be possible to close the pipeline inlet downstream in case the water is directed towards the fields. In that case, the stand pipe of the diversion & overflow is removed and the water flows out through the bottom outlet. This unit follows the exact same principles as the flush & overflow of the inspection chamber (Appendix A.3), with the only difference that the pipe ends in a consolidated open channel which is connected to the earthen channel network supplying the fields and not the river. It is important, that this transitional zone is constructed solidly, for instance with RCC or masonry work, to prevent scour and erosion.

The opening and closure of the pipeline inlet downstream ideally consists of a pipe gate. As mentioned before, that gate should make a quick opening and closing of the valve impossible in order to prevent unfavorable pressure surges. In case such pipe gates are not available or unreasonably expensive, notches may be incorporated in the wall to accommodate a wooden board (Figure 7.4). By inserting it, the outflow is obstructed and the water flows out through the diversion & overflow. Note that even if the stand pipe of the diversion & overflow (as depicted in Figure 7.3 in Appendix A.3) is not removed, the water will be directed to the fields through the overflow. Nevertheless, the stand pipe needs to be removable in order to allow particles to be flushed out as well as for maintenance tasks.

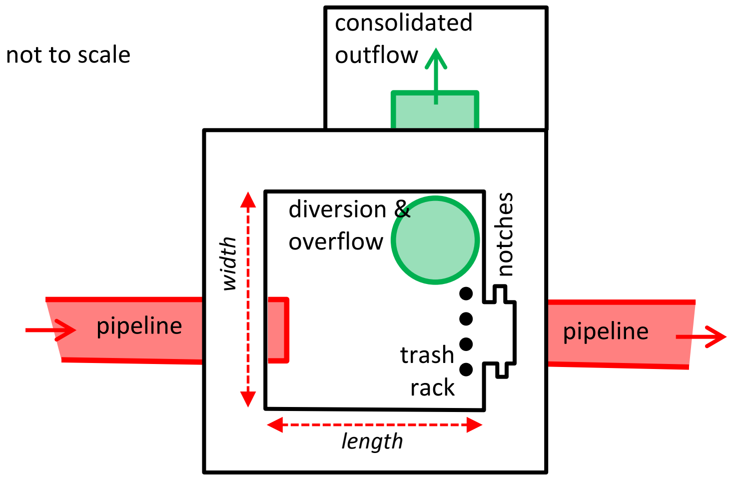


Figure 7.4: Schematic top view of a distribution chamber accommodating the incoming and outgoing pipeline, a vertical trash rack, notches allowing the insertion of a board closing the pipeline's inlet downstream, as well as a combined diversion & overflow unit. Note that the notches in the wall are only necessary in case a pipe gate is unreasonably expensive or not available (drawing not to scale).

Recommended approximate dimensions of the distribution chambers are presented in Table 7.3.

Table 7.3: Rough estimate of the distribution chamber's dimension. The values might have to be adjusted according to the site conditions.

Description	**Unit**	**Value**
Width of chamber	*(m)*	1.00
Length of chamber	*(m)*	1.00
Maximal water depth	*(m)*	0.80
Freeboard	*(m)*	0.30
Pipeline's diameter (OD)	*(m)*	0.16
Diversion & overflow's diameter (OD)	*(m)*	0.20

A.5 Fixing the broken gully crossing

Erosion at the base of the widest crossing's structure (C1) led to the interruption of the water supply system (Figure 7.5).

Figure 7.5: Gully crossing (C1) before and after the collapse taken place in summer 2013. ***Left:*** *The pipeline (red arrow) was fixed on a long wooden bar, which rested on stacked rocks on each side of the gully (photo: 11/05/2012, Daniel Bernet).* ***Right:*** *The base of the structure (green arrow) situated at the gully's right side (relative to the gully's flow direction indicated by the yellow arrow) was eroded, triggering the crossing's collapse. The wooden bar's right end, along with the fixed pipeline, fell into the gully, inactivating the water supply downstream. One of the two anchor blocks, holding the steel rope in place, is indicated by the blue arrow (photo: 27/09/2013, Daniel Bernet).*

The following observations have to be considered to fix the structure, prevent a future collapse and protect the slopes properly against erosion.

- The stacked rocks, on which the long wooden bar rested, were mostly supported by the thin base of the whole structure, making it very vulnerable to failure. As the base was located within the gully carrying water during storm events, it was only a question of time until the base was destabilized, causing the whole structure to collapse.
- The gabions placed on the gully's left side were not installed properly. Instead of protecting the slopes, it had rather the effect of concentrating the flow through the narrow passage, leading to even increased erosion.
- Unlike the stacked rocks, the two anchor blocks are situated away from the steep, unstable slopes and are therefore located at a safe location. Attaching the pipeline to the steel rope is therefore a favorable solution, as the system is not directly dependent on the stability of the exposed slopes. Nevertheless, these slopes have to protected in order to prevent backwards erosion, eventually also destabilizing the base of the anchor blocks.

A proposition of how the gully crossing can be fixed is presented in Figure 7.6. It is important that the gabions are properly placed. As can be seen in Figure 7.5, the stacked rocks were merely placed on the tilted slope, which constitutes a sliding plane rather than a solid base. To place any erosion protection measure, a horizontal plane has to be excavated on which the structures can be based.

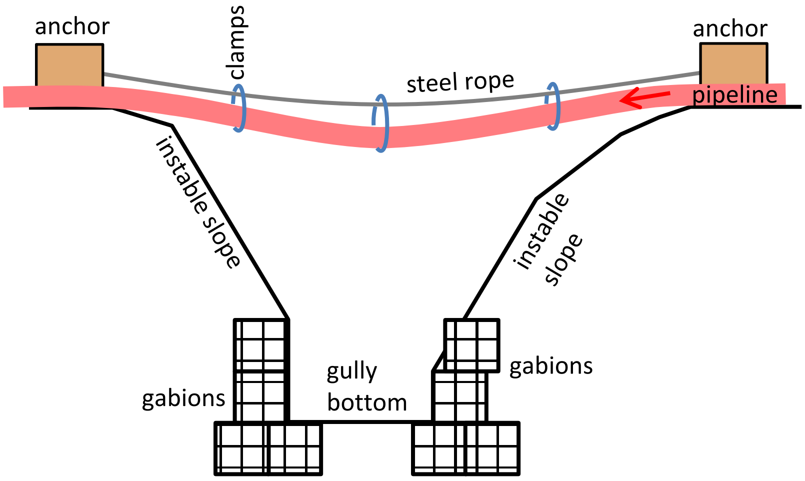


Figure 7.6: Cross-sectional sketch of the gully crossing seen from the same perspective as in Figure 7.5. The pipeline is recommended to be fixed on the steel rope with appropriate clamps (Figure 7.7). To prevent backward erosion, the instable slopes' bases have to be protected against erosion, ideally with gabions. It is crucial to place the gabions properly, namely below the gully bottom and into the slopes. Furthermore, the gully bottom needs to be cleared so that the water has as much space as possible to pass.

Because the used blank wire was not strong enough to carry the weight of the pipes, the pipeline could not be attached to the steel rope. To do so, iron clamps (Figure 7.7, left) and thin steel ropes should be applied, as described in Figure 7.7.

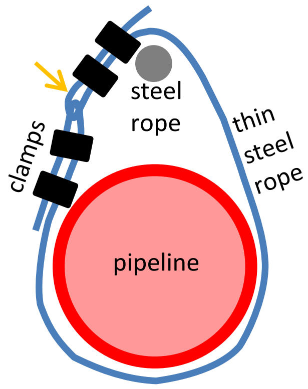


Figure 7.7: Proposed method to attach the pipeline to the steel rope. ***Left:*** *To the anchor blocks of the crossing C1 and C3, a 25 mm steel rope is fixed. To attach the pipeline to the rope, 10 mm steel ropes and appropriate clamps, like the ones depicted in the photograph, are recommended (photo: 29/09/2013, Daniel Bernet).* ***Right:*** *cross-sectional sketch of the attachment method. First a small loop (orange arrow) at one end of the thin steel rope should be formed and fixed tightly with clamps. The rope should then be looped around the transversal steel rope and the pipeline. Following, the thin steel rope's loose end should be laced through the before created loop and tightened. The loose end should finally be looped back, fixed with clamps and the surplus rope should be cut.*

B Location of leg A's units

The location of leg A's main units are specified in the following sections. The place along the pipeline axis related to the Intake (x = 0 m) and the coordinates, taken from Google Earth Pro, are indicated.

B.1 Inspection chambers

Figure 7.8: Position of the inspection chamber I1 (x = 210 m; 29°05'20.66"N / 84°00'38.52"E). ***Left:*** *Currently, the open channel runs along a cliff (orange arrow), which is destabilized by water percolating through the soil. The pipeline (red arrows) and the chamber (black rectangle) are proposed to be shifted inwards to be at a safe distance from the instable slope downhill (photo: 27/09/2013, Daniel Bernet).* ***Right:*** *Bird's eye view of the inspection chamber's location. The red line indicates the pipeline, the orange arrow highlights the current routing of the open, earthen channel and the yellow arrow points in Puyung Khola's flow direction (source: Google Earth Pro, accessed 30/01/2014).*

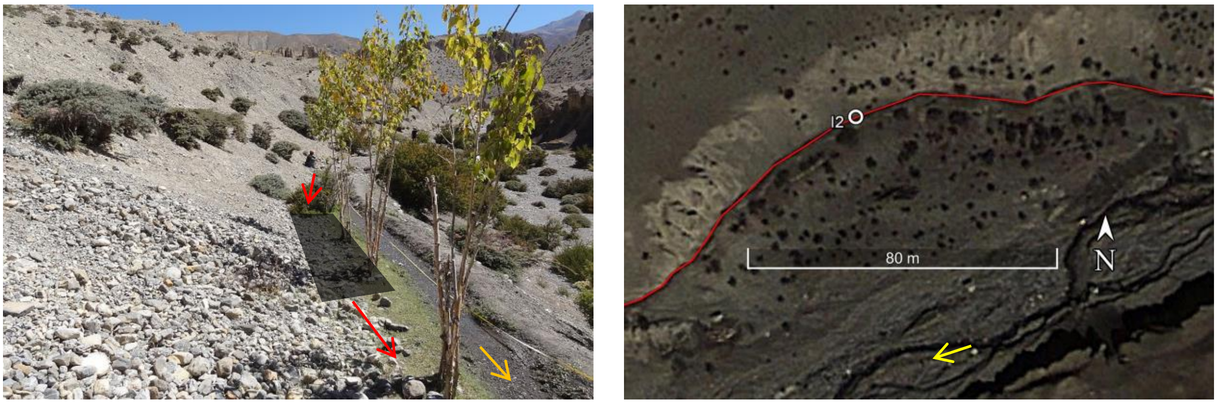


Figure 7.9: Position of the inspection chamber I2 (x = 388 m; 29°05'20.04"N / 84°00'32.12"E). ***Left:*** *The pipeline (red arrows) and the chamber (black rectangle) are proposed to be shifted slightly inwards to be at a safe distance from the instable slope downhill. The open, earthen channel is highlighted by the orange arrow (photo: 27/09/2013, Daniel Bernet).* ***Right:*** *Bird's eye view of the inspection chamber's location. The red line indicates the pipeline and the yellow arrow points in Puyung Khola's flow direction (source: Google Earth Pro, accessed 30/01/2014).*

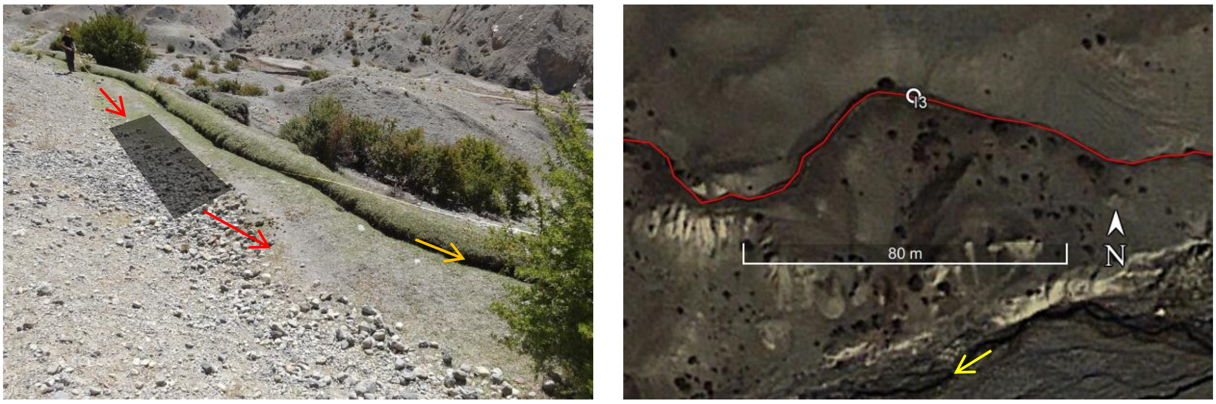


Figure 7.10: Position of the inspection chamber I3 (x = 564 m; 29°05'18.76"N / 84°00'26.47"E). ***Left:*** *The pipeline (red arrows) and the chamber (black rectangle) are proposed to be shifted slightly inwards to be at a safe distance from the instable slope downhill. The open, earthen channel is highlighted by the orange arrow (photo: 27/09/2013, Daniel Bernet).* ***Right:*** *Bird's eye view of the inspection chamber's location. The red line indicates the pipeline and the yellow arrow points in Puyung Khola's flow direction (source: Google Earth Pro, accessed 30/01/2014).*

C Location of leg B's units

The location of leg B's main units are specified in the following sections. The place along the pipeline axis related to the Intake (x = 0 m) and the coordinates, taken from Google Earth Pro, are indicated.

C.1 Inspection chamber

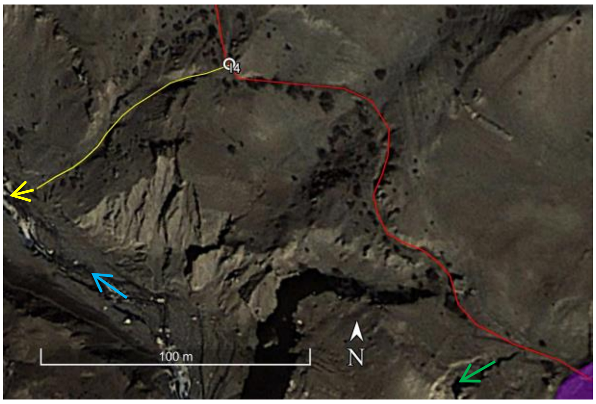
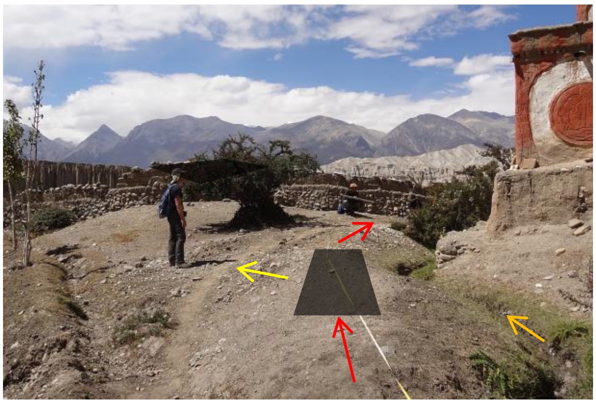


*Figure 7.11: Position of the inspection chamber I4 (x = 959 m; 29°05'24. 08"N / 84°00'16.40"E). **Left:** The pipeline (red arrow) and the chamber (black rectangle) are proposed to be located at the illustrated position (photo: 27/09/2013, Daniel Bernet). **Right:** Bird's eye view of the inspection chamber's location. The red line indicates the pipeline, the yellow line highlights the routing of the flush pipe (Figure 7.11), the blue arrow points in the river's flow direction and the green arrow indicates the backward erosion caused by diverting water from the reservoir (violet area) to the river (source: Google Earth Pro, accessed 30/01/2014).*

Figure 7.12: The routing of the 95 m long flush pipe connecting the inspection chamber I4 with the Puyung Khola is indicated by the yellow arrow. The installation of this pipe is important, as neglecting the safe discharge might lead to severe backward erosion endangering the stability of the future pipeline (photo: 27/09/2012, Daniel Bernet).

C.2 Distribution chambers



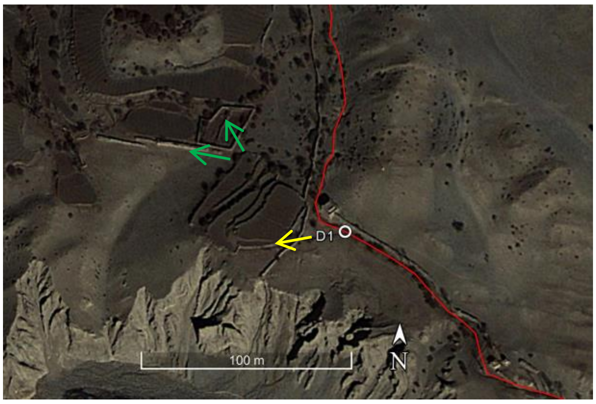


Figure 7.13: Position of the distribution chamber D1 (x = 1292 m; 29°05'31.07"N / 84°00'09.08"E). ***Left:*** *The pipeline (red arrow) and the chamber (black rectangle) are proposed to be located just next to the open distribution channel, indicated by the orange arrow (photo: 27/09/2013, Daniel Bernet).* ***Right:*** *Bird's eye view of the inspection chamber's location. The red line indicates the pipeline, the yellow arrow highlights where the chamber's diversion pipe should meet the open channel network to distribute the water to the corresponding field area, indicated by the green arrows (source: Google Earth Pro, accessed 30/01/2014).*

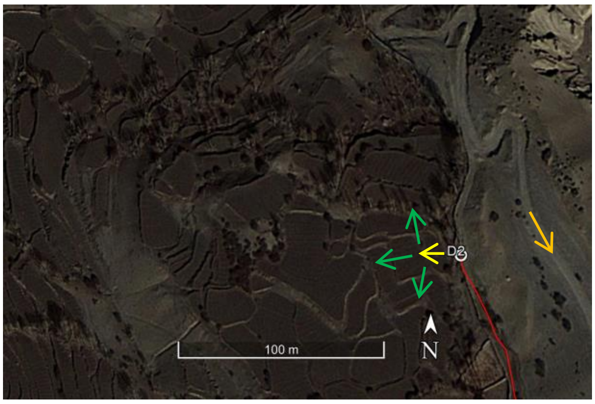
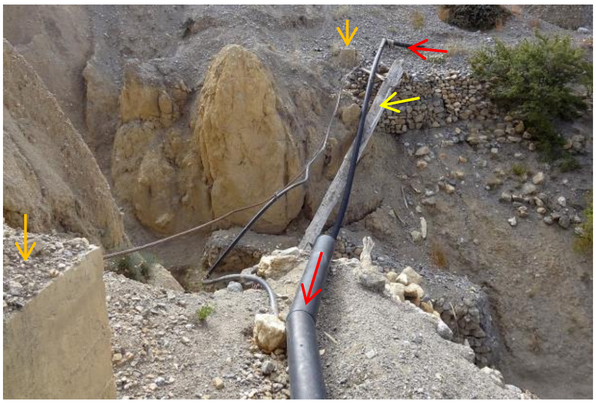


Figure 7.14: Position of the distribution chamber D2 (x = 1475 m; 29°05'36.57"N / 84°00'07.71"E). ***Left:*** *The pipeline (red arrow) and the chamber (black rectangle) are proposed to be located at the illustrated position (photo: 27/09/2013, Daniel Bernet).* ***Right:*** *Bird's eye view of the inspection chamber's location. The red line indicates the pipeline, the yellow arrow highlights where the chamber's diversion pipe should meet the open channel network to distribute the water to the corresponding field area (green arrows). The path leading to Ghara is highlighted by an orange arrow (source: Google Earth Pro, accessed 30/01/2014).*

D Location of leg C's units

The location of leg C's main units are specified in the following sections. The place along the pipeline axis related to the Intake (x = 0 m) and the coordinates, taken from Google Earth Pro, are indicated.

D.1 Gully crossings



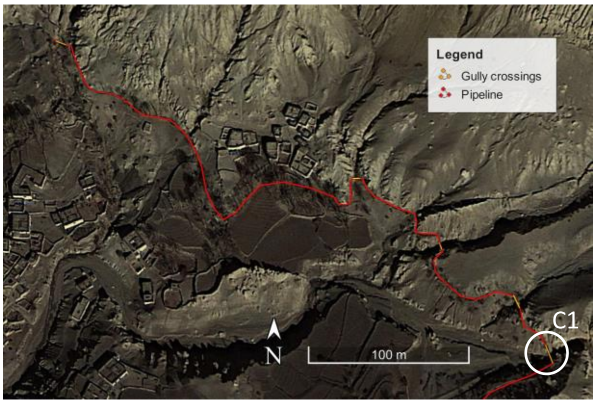


Figure 7.15: Position of the gully crossing C1 (x = 1649 - 1666 m; 29°05'41.25"N / 84°00'09.07"E). ***Left:*** *The pipeline (red arrow) was fixed on a long wooden bar (yellow arrow), which rested on gabion structures. The base of these gabions was eroded which triggered the crossing's collapse. On the steel rope, held by two concrete anchors (orange arrows), only the drinking pipeline was fixed, which is currently not used anymore (photo: 26/09/2013, Daniel Bernet).* ***Right:*** *Marked location of the gully crossing (source: Google Earth Pro, accessed 31/01/2014).*

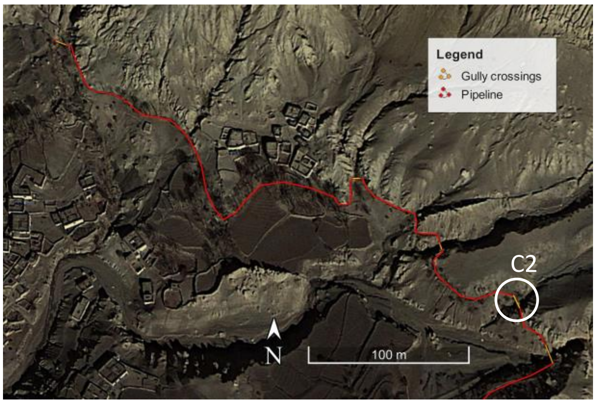


Figure 7.16: Position of the gully crossing C2 (x = 1685 - 1698 m; 29°05'42.26"N / 84°00'08.41"E). ***Left:*** *The pipeline (red arrow) is supported by two wooden Y-bars standing on stepped gabions on each side of the gully (yellow arrow). The open channel currently in use (orange arrow) can be seen in the background (photo: 11/05/2012, Daniel Bernet).* ***Right:*** *Marked location of the gully crossing (source: Google Earth Pro, accessed 31/01/2014).*

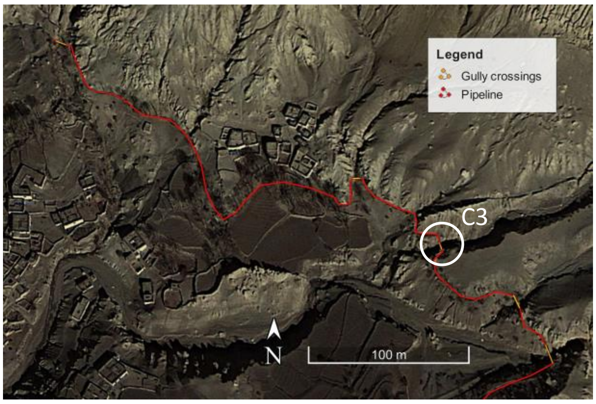


*Figure 7.17: Position of the gully crossing C3 (x = 1769 - 1781 m; 29°05'43.40"N/ 84°00'06.67"E). **Left:** The pipeline (red arrow) is attached to a steel rope, held by two concrete anchors, one of which is visible (orange arrow). The flow direction within the gully is indicated by the yellow arrow (photo: 26/09/2013, Daniel Bernet). **Right:** Marked location of the gully crossing (source: Google Earth Pro, accessed 31/01/2014).*

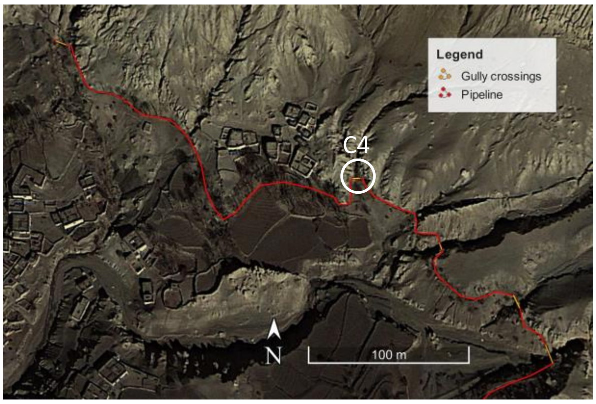


*Figure 7.18: Position of the gully crossing C4 (x = 1850 - 1854 m; 29°05'44.70"N / 84°00'04.75"E). **Left:** The pipeline (red arrow) crossing the small gully (yellow arrow) rests on a wooden bar (photo: 27/09/2013, Daniel Bernet). **Right:** Marked location of the gully crossing (source: Google Earth Pro, accessed 31/01/2014).*

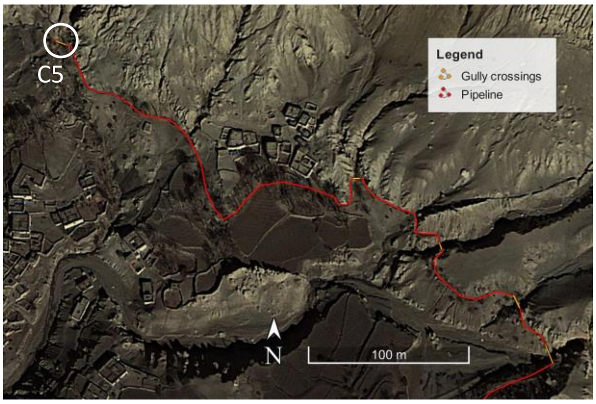


Figure 7.19: Position of the gully crossing C5 (x = 2127 - 2134 m; 29°05'47.41"N / 83°59'58.05"E). ***Left:*** *The open channel (white arrow) is connected to a log with a carved-in slot (orange arrow), spanning over the small gully, indicated by the yellow arrow (photo: 27/09/2013, Daniel Bernet).* ***Right:*** *Marked location of the gully crossing (source: Google Earth Pro, accessed 31/01/2014).*

D.2 Distribution chamber

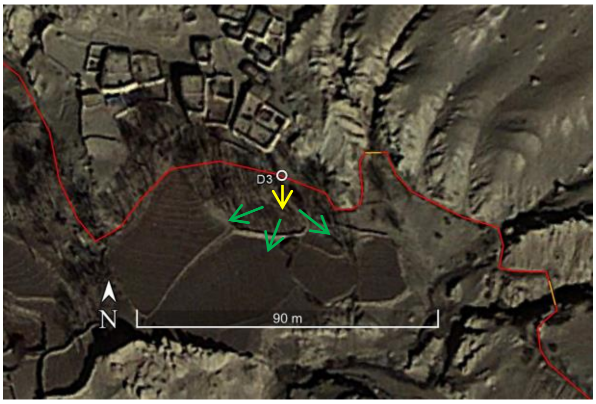


Figure 7.20: Position of the distribution chamber D3 (x = 1882 m; 29°05'44.51"N / 84°00'03.79"E). ***Left:*** *The pipeline (red arrow) and the chamber (black rectangle) are proposed to be located on top of the open distribution channel (photo: 27/09/2013, Daniel Bernet).* ***Right:*** *Bird's eye view of the inspection chamber's location. The red line indicates the pipeline with gully crossings (orange sections), the yellow arrow highlights where the chamber's diversion pipe should meet the open channel network to distribute the water to the corresponding field area indicated by the green arrows (source: Google Earth Pro, accessed 30/01/2014).*

D.3 Outlet structure

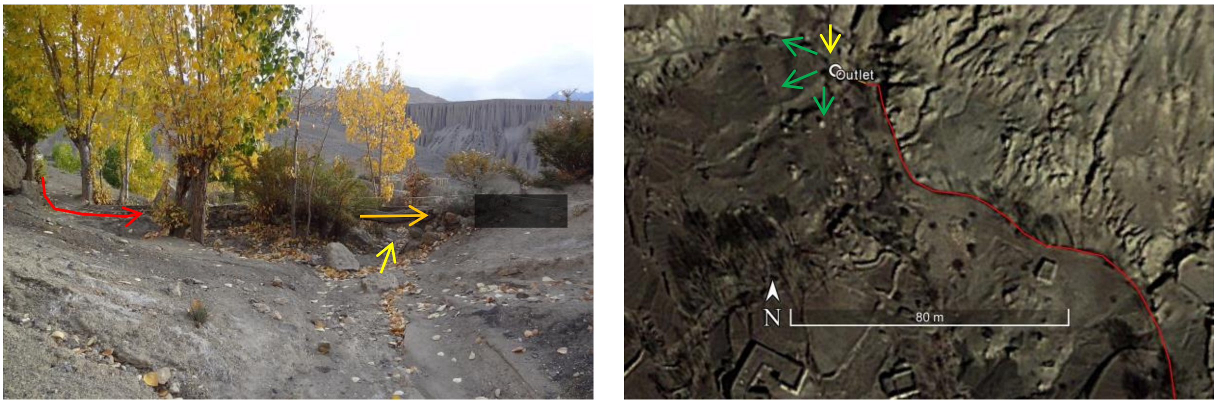


*Figure 7.21: Position of the irrigation water supply pipeline's outlet (x = 2134 m; 29°05'47.49"N / 83°59'57.83"E). **Left:** The pipeline (red arrow) crosses the gully (yellow arrow) supported by a wooden bar (orange arrow) and merges into the outlet structure, indicated by the black rectangle (photo: 27/09/2013, Daniel Bernet). **Right:** Bird's eye view of the outlet's location. The red line indicates the pipeline and the yellow arrow the gully, which has to be crossed just before the pipeline ends. From the outlet, the water can be brought to the corresponding fields by the open channel network indicated by the green arrows (source: Google Earth Pro, accessed 30/01/2014).*

E Prize list

E.1 HDPE pipes, Panchakanya

Panchakanya
PLASTIC INDUSTRIES (P) LTD.

Head Office: Krishna Galli, Lalitpur, Nepal,. Tel.: 977-1-5526357, 5526551, Fax: 977-1-5526529
E-mail: pkplast@panchakanya.com.np, www.panchakanya.org, Mailing Address: G.P.O. Box: 2743, Kathmandu, Nepal

Manufacturer of HDPE Pipes & Accessories
Price for HDPE Pipes Manufactured as per NS 40/040
(Effective from July 16, 2008)
2065 Sharawan 1

Size in Mm	Size in Inch	Pressure (2.5 Kgf/cm²) Price/Mtr.	Pressure (4 Kgf/cm²) Price/Mtr.	Pressure (6 Kgf/cm²) Price/Mtr.	Pressure (10 Kgf/cm²) Price/Mtr.
16 mm		-	-	-	21.62
20 mm	½"	-	-	-	31.49
25 mm	¾"	-	-	-	47.47
32 mm	1"	-	-	53.11	78.49
40 mm	1¼"	-	58.99	82.25	120.79
50 mm	1½"	-	88.83	127.37	187.06
63 mm	2"	94.71	137.48	199.75	298.22
75 mm	2½"	130.90	198.81	279.89	418.77
90 mm	3"	187.77	286.70	403.50	603.48
110 mm	4"	278.48	400.21	598.08	893.24
125 mm	4½"	359.55	537.92	773.86	1166.07
140 mm	5"	445.80	681.74	975.25	1459.12
160 mm	6"	576.46	886.66	1258.43	1898.57
180 mm	7"	739.78	1119.07	1598.00	2410.16
200 mm	8"	910.63	1384.15	1971.89	2965.70
225 mm	9"	1133.17	1749.58	2477.84	3763.29
250 mm	10"	1412.82	2158.95	3064.64	4642.90
280 mm	11"	1755.69	2691.93	3836.85	5806.38
315 mm	12"	2213.00	3409.38	4863.09	7322.60
355 mm	14"	2989.25	4595.50	6560.75	9908.75
400 mm	16"	3653.04	5602.32	7994.16	-

TERMS & CONDITIONS :-

1. Above prices are Ex-Factory Bhairahawa, exclusive of 13% VAT.
2. This price list supersedes all our previous price list.
3. The prices are subject to change without any prior notice.
4. 100 % payment should be made before delivery.
5. Force majeure clause shall apply.

ISO 9001:2000

Factory: Kotehawa. Siddhartha Nagar. Bhairahawa. Nepal. Tel: 977-71-560371, 560571, Fax: 977-71-560574

Figure 7.22: Panchakanya HDPE pipe prize list as per spring 2013. Note that generally at least 13 % discount is granted, so that the 13 % VAT, in addition to the stated rate, do not have to be considered.