No. 84 Report
of the Research Institute for Hydraulics
Hydrology and Glaciology

at the Zurich Federal Institute of Technology
Edited by Professor Dr. D. Vischer

SWISS RIVER TRAINING IN THE 18th AND 19th CENTURIES

Daniel Vischer

Zurich, 1986

AUTHORISED ENGLISH EDITION

PUBLICATION NO. 14 OF THE HYDROLOGY CENTRE, CHRISTCHURCH

Christchurch, New Zealand

With my best wishes for 1989
Daniel Vischer

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Possible reasons for river training projects on the Swiss plateau are discussed. The training of the River Kander (1711 - 1714) is presented as the starting point of some 40 works in the 19th Century. Two examples, the Linth and the Jura, are described in detail.

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FOREWORD

Friedrich Rückert wrote the poem: *"Chidher, der ewig Junge"* (Chidher, the eternal youth). It deals with a wanderer, of whom a great many tales have been told. Every 500 years he passes by the same place, and every time he discovers a different landscape there; first of all it is a town, then a pasture, then an ocean, then a forest, then a town again. Each time Chidher asks the inhabitants about the origin of their environment, but they do not know, and are of the opinion that it has always appeared as they now see it. "The town stood always on this land and forever will so stand", one townsperson said to him, for example. In an impressionable way the poem expresses how little a person is able to perceive gradual changes in his environment, and how very much he is bound by the present and his actions.

The author often thinks of this poem whilst observing one of the large Swiss valley plains. What would Chidher have seen and discovered from the inhabitants 200 years ago, in, for example, the Linth plain, the "Grossen Moos" (Great Moor) or the Rhine valley at St. Gallen? At that time the landscape would have been characterized by braided meandering rivers. As well as extensive gravel areas there were wild valley forests and fields of waving reeds. The swamps and unsafe flood plains associated with these landscape features allowed only limited agriculture and forestry. There were correspondingly few inhabitants, who were poor in relation to the rest of the population. If Chidher could have asked, they would have told him pessimistically about the repeated flooding of the rivers, the putrid vapour from the swamps, and the malaria.

What would Chidher see today - and what do we see ourselves? The rivers have been straightened and stopbanked. The valley plains consist of fertile pastures and fields, or extensive cultivated forests. On the plains, settlements and traffic routes proliferate. The inhabitants are healthy and enterprising. In comparison to the mountain folk they are regarded as advantaged and rich. But how would they answer Chidher's questions? Certainly they would be bound to their present situation just as much as their ancestors 200 years ago. They would probably complain about over-population and over-development, and the increasing amount of air pollution due to the traffic.

However, the present author would not like to judge this point. To him the one attitude is as understandable as the other. He is more concerned with the fascinating change in landscape and population, within, at the most, 200 years.

Therefore, this report is an attempt to pursue the reasons for the change. These are mainly connected with the great river training works conducted in the 18th and 19th centuries.

The author was willingly supported in the acquisition of the facts by Mr Andreas Goetz, manager of the department for 'River Construction, Regulation of Discharge and General Water Supply and Distribution' of the Federal Office for Waterworks, as well as Mr Hans Rohner, manager of the department for Rhine Training of the Cantonal Office for Water and Energy Supply and Distribution, St. Gallen. Many thanks to both gentlemen!

D. Vischer

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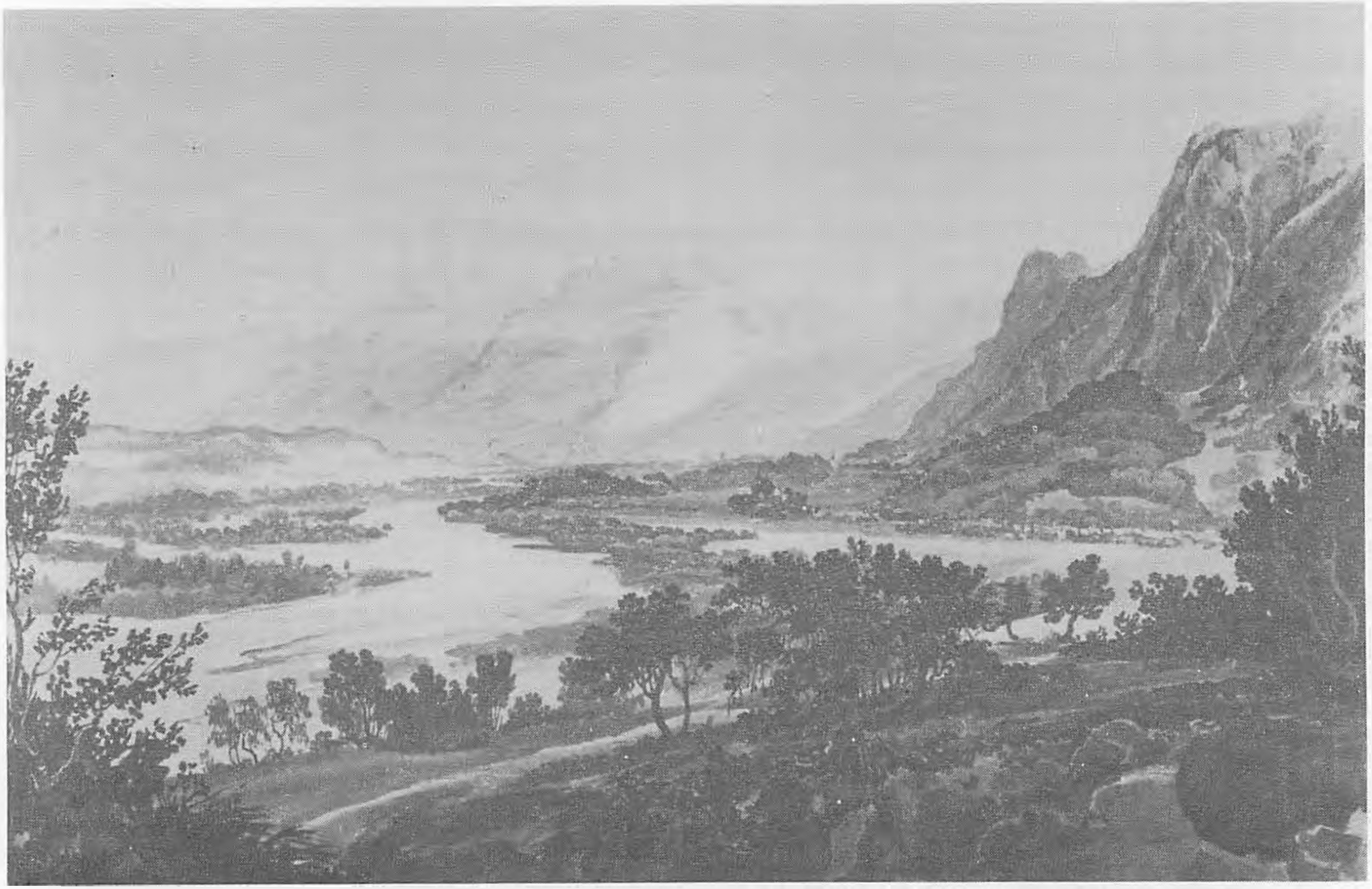


Illustration 1: *Rhine Valley at St. Gallen about 1830 (before the training of the Rhine). View upstream from Blattenburg. Mouth of the Ill on the left, the High Kasten mountain on the right.*

Summary

The 19th century can rightly be called the century of the Swiss river training works. Nearly all the larger training projects were achieved then, or at least initiated.

The following contribution focusses on the rivers of the Swiss plateau. First the author deals with the possible reasons for the various training projects. Then he presents the training of the river Kander in the years 1711 to 1714 as the starting point of a development which lead in the 19th century to some 40 river training works. As outstanding examples, the training works of the river Linth and the waters of the Jura are described in detail. Because of their combination of river training with lake regulation they are typical Swiss solutions for flood control.

The reproduction of many contemporary pictures illustrates the building art and techniques of those times.

Illustration 2: *"Scene from the flooding of the Rhine valley at St. Gallen in Autumn 1868 - as it really was, drawn by E. Rittmeier", from Senn's character-portraits, Bern.*

1. Reasons for river training

The history of Swiss water engineering and Swiss river training has not previously been documented. Therefore, no general view has been put forward, to associate these great technical operations with their political and economic environments. This is surprising because river training has changed the face of Switzerland, probably more than some of the important events described in history books. Perhaps the ensuing information will stimulate an historian to take up the matter.

The following questions in particular require resolution:

What necessitated the river training projects? Why did Swiss hydraulic engineering suddenly boom around the 1800's? Why was it that the larger river training projects were initiated in the 19th century?

There were undoubtedly several reasons for the development; the author, an engineer and not an historian, assumes the following four :

- an accumulation of devastating floods during the 18th and 19th centuries
- land reclamation by a growing population in the 19th century
- change of political structures after the fall of the old confederation in 1798
- development of river engineering techniques in the 18th century.

Some chronicles and old scripts on water engineering report that floods increased in size and frequency in the 18th century, and by the 19th century often assumed catastrophic dimensions. The small dykes, used locally to restrict the rivers within their boundaries, became less effective in containing the large floods. The river beds widened continually. The river Rhine at St Gallen may be' taken as an example. In the 17th century only the occasional bursting of dykes with corresponding flooding had to be endured. However, in the 18th century this happened 17 times, and in the 19th century, 20 times - every five to six years on average. These same floods also caused the shores of lakes to be inundated.

Illustration 3: *Flooding in 1717. "Image of the Great Flood which, under the hand of God, covered much of the land on December 25 and 26, 1717 AD and from which many people, cattle, houses and possessions perished and were completely destroyed. Joh. Melchior Fuesslinus del. et fecit" (Graphic collection ETH).*

The reasons for this development probably lay in a change of the river catchments and climate. Recent investigations reveal detectable fluctuations in the climate of Switzerland which included both flood-free periods and periods of flooding. The effects of the assumed deterioration in climate were aggravated by human activity which increased the movement of sand and gravel in streams and rivers and in turn raised the level of the river beds. An eloquent portrayal of the conditions in the Linth river catchment of the Glarus canton is given by Becker (1910):

> *"In the 18th century a new industry, that of cotton and its affiliated branches, ... developed in this canton, transforming the style of living. This change in lifestyle resulted in rapid economic growth, but it also brought with it a heavy demand for wood. In addition to domestic consumption, timber was exported to Holland - a direct result of the cotton trade to this region. Whole forests were felled for the Dutch. At one stage, they wanted to burst the rock-reef of the Rhine waterfall in order to float the tree-trunks downstream from the forests of Bavaria*

and Vorarlberg unhindered .... The exploitation of the forests without careful handling and without reafforestation - one was accustomed at that time to take from the land without putting anything back in return - inevitably generated a sequence of negative results. Destruction of the hillsides and valley floors was the outcome. Devastation occurred all over the country due to avalanches and land slides and also due to the accumulation of rubble in valley rivers and streams."

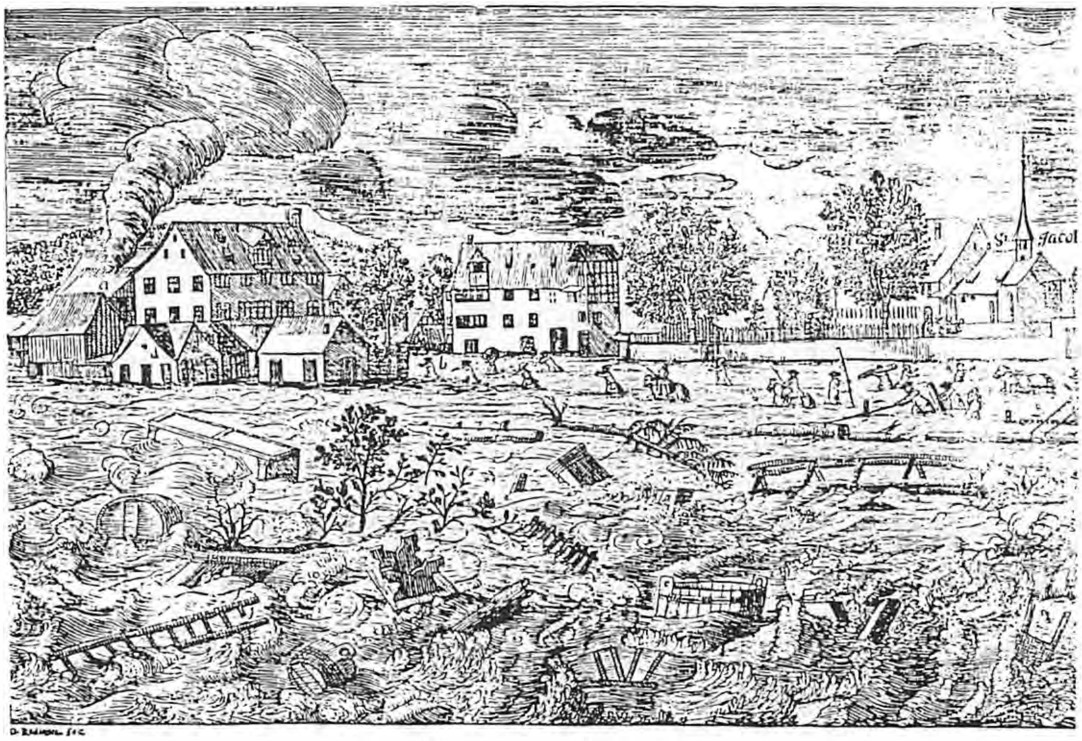


Illustration 4: *Flooding of the Sihl in Zurich "D.Redinger fecit" 1732 (Graphic collection ETH).*

The persistent overflowing of rivers and brooks became a public nuisance in many areas. Settlements and farmlands were destroyed and people and cattle died in the rapidly rising and hence quickly spreading floods.

The incidence of malaria increased with the expansion of wetland areas. Moving reports describe certain events such as the black day at the river Emme, portrayed in the narrative by Jeremias Gotthelf: *"Flooding in the Emmenthal valley on August 13, 1837"*. Had such events repeated themselves within a few years of each other they would have eventually put a stop to all constructive developments. A despair-stricken population, afflicted with starvation and illness, remained. It is no wonder that there were increasing calls for effective flood protection. This soon mobilized large parts of the population and compelled the authorities responsible to take action. The first projects for the execution of the great river training operations were without doubt a result of this palpable emergency.

Further activity was probably spurred on by the success of these first measures for flood protection. Both settlements and farmland were successfully protected from the waters of large and small rivers. The enlargement of areas of swamp was halted. People began to reclaim their farmland from the rivers. To achieve this, rivers were dammed, lake levels were lowered and moors were drained. The growing population, as a result of industrialisation, obviously needed more living space. This had to be found inland because political developments precluded the relocation of borders and it was impossible to establish colonies. The land reclamation could also be interpreted as a type of self-colonisation as it was in fact, later, termed. A picture of the mood around the turn of the 18th century is given by a rather extraordinary sequence of events when judged by today's standards:

In 1788 work began in the Obwalden canton on a tunnel about 420 m long. The intention was to tap Lake Lungern in order to drop its water level to obtain more farmland. To begin with, technical problems hampered construction, then the French invasion of 1798 brought the operation to a complete standstill. In 1806 construction resumed once again and was finished, despite various setbacks, in 1836. The result was pleasing - the level of Lake Lungern fell by nearly 40 m and the surface area was reduced from 2.1 km^2 to 0.8 km^2. The amount of reclaimable land was 1.3 km^2 or 130 hectares. The jubilation to be heard throughout Switzerland following this success was somewhat dampened by the subsequent occurrence of extensive bankslides. Much later, in 1920, in connection with the building of power stations, Lake Lungern was dammed again to reach almost its original level. Due to this operation the lake attained its present dimensions.

Illustration 5: *Flooding in the river Toess 1876, drawing by Joh. Weber (central library, Zurich).*

Before 1800 only regional river training had been planned and realized, as, for example, the training of the Kander river from 1711 to 1714 and the fore-mentioned attempt to lower Lake Lungern in 1788. It was only with the fall of the old confederation that impediments to inter-regional or federal planning were removed. Obviously, new political structures and, in particular, a stronger central power were needed for such planning. The Mediation constitution of 1803 achieved, if only partially, this status. It enabled the decision by the Federal Diet of 1805 to carry out training of the Linth river - a type of co-operative venture serving four cantons, namely: Zurich, Schwyz, Glarus and St. Gallen.

Because, at the time of the Mediation, the destiny of Switzerland was determined by the increasing power enjoyed by Napoleon, an influence from abroad can be assumed; the extensive Napoleonic road and canal construction in Europe highlighted the need for inter-regional co-operation. Moreover, the great river training operations already begun in neighbouring countries provoked imitation by the Swiss.

The Swiss President living at the time of the Mediation repeatedly approached the grand duke of Baden to ensure the services of the excellent river engineer, Johann Gottfried Tulla, also from Baden.

Illustration 6:
Johann Gottfried Tulla (1770-1828)

Tulla dedicated his energies in 1807 and 1808 to the training of the river Linth. Until 1812, in the course of several journeys through Switzerland, he elaborated on studies for the training of the rivers Birs, Reuss, Alpine Rhine, Aare and the waters near the Jura. His greatest achievement, however, was the river training in the Upper Rhine area from Basel to Worms. He personally directed the execution of this from 1817 until his death in 1828. The work was not completed until 1874. In 1812 his memoir *"Principles for Future Construction on the Rhine"* was published. It contains the famous maxim - "No stream or river, not even the Rhine requires more than *one* riverbed, or likewise, no stream or river requires *as a rule* more than one riverbed."

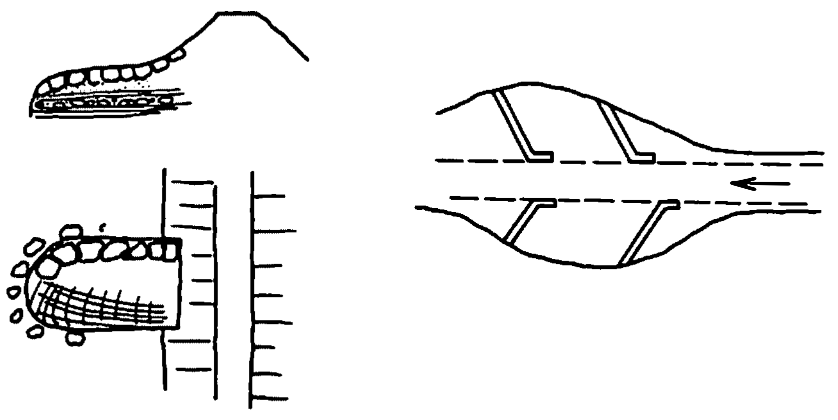


Illustration 7: *Sketch from a letter written by Tulla to J J Schaefer, Basel, for training of the river Birs (according to Golder 1984).*

The influence Tulla had on Swiss river training raises the question about the state of river engineering at that time. The theoretical basis of hydromechanics was founded at the beginning of the 18th century as a result of competent co-operation by three scholars in Basel: Daniel Bernoulli's book *"Hydrodynamica"* was published in Strasbourg in 1738, Johann Bernoulli's book *"Hydraulica"* in Lausanne in 1742, and from 1755 various writings by Leonhard Euler relevant to the topic were published in Berlin and Petersburg. Initially, however, these theories could only be applied to currents without friction, and therefore principally to water currents within pipes. A formula taking into account the friction within liquids was indispensable for the treatment of river currents. Such a formula was first devised by the Frenchman Antoine Chézy in 1768 and applied to a canal project, although the professional world did not recognize its significance. The theory expounded in the book *"Manual for the Mechanics of Solid Bodies and Hydraulics"* written by the Prussian engineer Johann Albert Eytelwein and published in 1801 was the first one to be put into practise. It, in principle, suggested the same formula.

Two publications were especially revolutionary in the field of river engineering : the book *"Scene of Water Engineering"* written in 1724 by Jacob Leupold, royal Prussian Councillor in Berlin, and the four volumes *"Architecture Hydraulique"* written between 1737 and 1753 by Bernard Forest de Bélidor, provincial commissioner of the artillery and the royal professor at the school of the Artillerie-Corps in France. Bélidor's volumes, in particular, were regarded as standard works in the following 100 years. They were published several times and translated into German and other languages.

Illustration 8: *Bernard Forest de Bélidor (1697-1761)*

On the basis of Bélidor's four volumes and also Dutch literature, the following specialist books appeared in German:

1766 Johann Esaias Silberschlag, Pastor at the "Heilige Geistkirche" in Magdeburg:
"Treatise on Hydraulic-Engineering in Rivers", Leipzig.

1767 Johann Baptist Eberenz, Engineer and royal water engineering director, etc. in Freiburg, Breisgau:
"Initial Theories on Hydraulic Engineering in Torrential Rivers" (quoted by Silberschlag, 1772).

1767 Lucas Voch, Architect and Engineer:
"Manual on Water Engineering in Small and Large Rivers", Augsburg.

1772/73 Johann Esaias Silberschlag, Royal Prussian Senior Advisor for River Engineering, etc. in Berlin:
"Extensive Treatise on Hydrotechnics or Hydraulic Engineering" Leipzig (2 volumes).

1791/99 Reinhard Woltman, Director of the bank and water engineering works in the Hamburg Office, Ritzebüttel:
"Contribution to Hydraulic Architecture", Göttingen (4 volumes).

1802/08 Johann Albert Eytelwein, Royal Prussian Advisor for Engineering in Berlin:
"Practical Instruction for Hydraulic Engineering", Berlin (4 volumes, the first two with David Gilly as first author).

1811/17 Carl Friedrich Wiebeking, Royal Bavarian General-Director of Water, Bridge and Street Construction etc. in Munich:
"Theoretical-Practical Hydraulic Engineering", Munich (4 volumes).

From the Swiss point of view it is of interest that the Swiss General Guillaume Henri Dufour presented a seminar about Hydraulics in Geneva in 1839. Part of it concerned the "Theory about Rivers" ("Théorie des Fleuves") and has been preserved as a manuscript.

In view of all these theoretical and practical contributions it can be assumed that the development of river engineering took place mainly in the second half of the 18th century and brought with it, therefore, the actual prerequisites for extensive river training.

Certainly river training operations were not effective alone. They were effective in connection with one another, although the degree of effect was often diverse. As already indicated, this era of river training was not only confined to Switzerland, but extended over large parts of Europe. *"Faust II"*, the drama by Johann Wolfgang Goethe (published in 1832) imparts an impressive image according to the time. It finishes with a water engineering vision, when the dying Faust says:

"A chain of marshes lines the hills,
Befouling all the land retrievement;
To drain this stagnant pool of ills
Would be the crowning, last achievement.
I'd open room to live for millions
Not safely, but in free resilience.
Lush fallow then to man and cattle yields
Swift crops and comforts from the maiden fields.
New homesteads near the trusty buttress-face
Walled by a bold and horny-handed race.

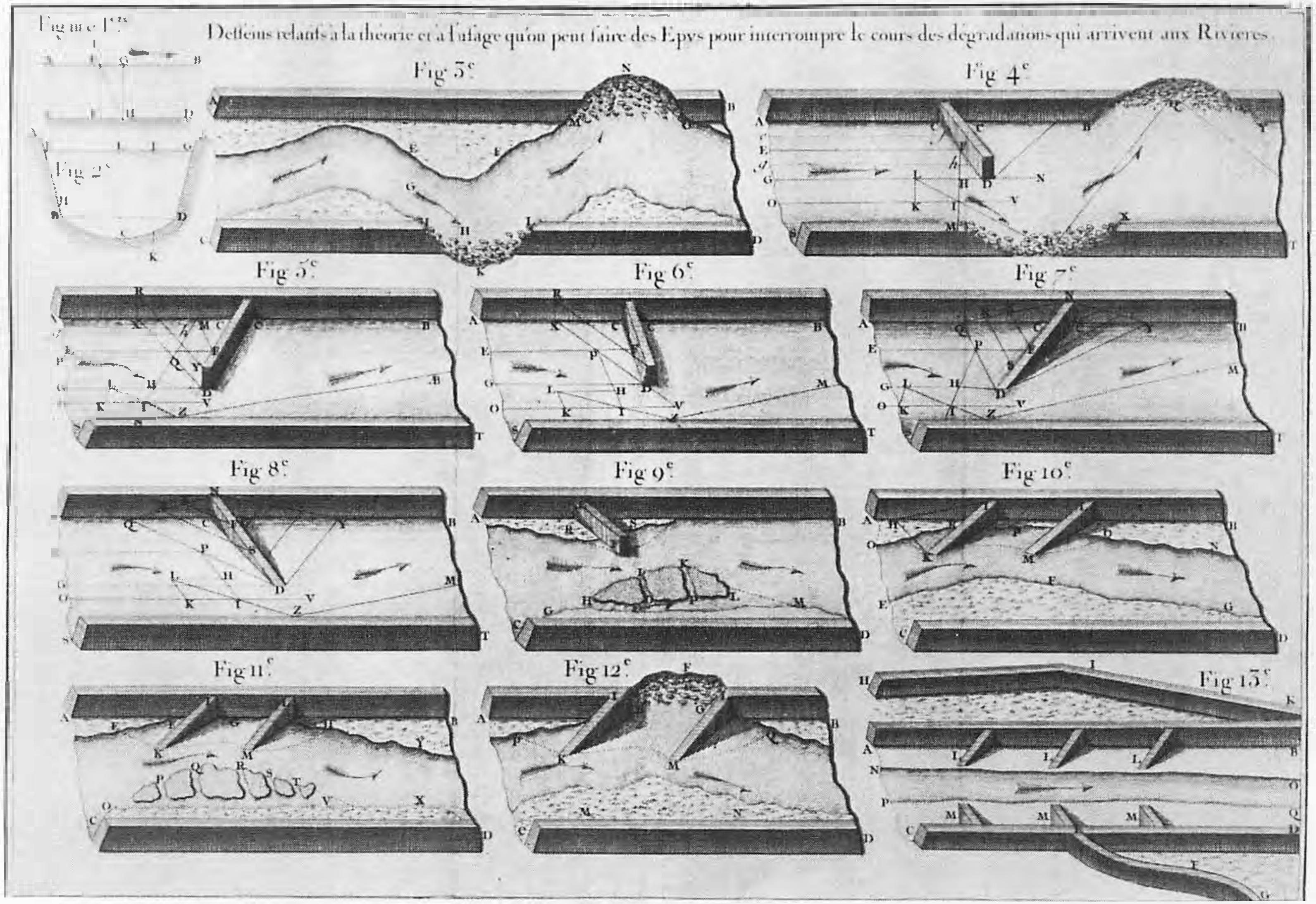


Illustration 9: *Inset of Spurs and Groynes according to Bélidor 1737*

A land of Eden sheltered here within,
Let tempest rage outside unto the rim,
And as it laps a breach in greedy riot,
Communal spirit hastens to defy it.
Yes - this I hold to with devout insistence,
Wisdom's last verdict goes to say:
He only earns both freedom and existence
Who must reconquer them each day.

And so, ringed all about by perils, here
Youth, manhood, age will spend their strenuous year
Such teeming would I see upon this land,
On acres free among free people stand,
I might entreat the fleeting minute:
O tarry yet, thou art so fair
My path on earth, the trace I leave within it
Eons untold cannot impair".

(Taken from: Faust - Johann Wolfgang von Goethe:
A new Translation by Walter Arndt. ed. Cyrus Hamlin
1976 W W Norton and Company Inc. (ll.11559-11584)

Goethe visited Switzerland several times in 1800 and recognised its problems. It is also known that he took an interest in the construction of dams which had been erected in 1825 after severe flooding on the lower Elbe due to a storm. Thus Faustian vision had an historical background.

From this quote one can also maintain that the river training of the 19th century still adheres to what we describe as "Faustian" even today. The population, who earlier sustained flooding and malaria, and who had endured the situation apathetically, now rose in a resolute manner and declared war against these overflowing rivers. They consciously battled against this natural force which possessed, at that time, an almost supernatural character. Success was finally achieved by man, thus verifying his power, promoting unity among the population, raising their self-confidence and, above all, establishing new areas for living and new opportunities for development.

The consequence was naturally a permanent alteration to the landscape. Whereas previously many valley floors in Switzerland had belonged to the rivers, man now took possession of them. The valley meadows, shaped by the many river branches, with countless islands, and adjoining swamps had to be forfeited for intensive farming and grazing land. One may, from today's viewpoint find it regrettable that man's encroachment onto some areas of land previously occupied by rivers resulted in the riverbeds taking the shape of straight, narrow channels. But at that time it was different - great poverty was still experienced by a large part of the population and there were many calls for redress. This need for redress developed into a type of effective self-help which today warrants admiration. The river training operations perhaps bore the semblance to something Faustian, but at least peaceful means were used. The conquest of the Swiss valley-floors was achieved by means of shovels, picks and wheelbarrows, as opposed to guns used in wars. Therefore, it has been said, with regard to the training of the river Linth (a project begun in 1807), that this was the first un-warlike enterprise of the confederate diet. In fact the era of Swiss river training in the 19th century was a remarkably peaceful one.

Illustration 10: *Correction of the river Rhone near Raron (strenuous physical labour for both men and women). Painting by Raphael Ritz, 1888 (Sitten town hall).*

2. Training of the Kander River (1711-1714)

The Lords of Bern were the first to carry out extensive river training in Switzerland. They diverted the Kander river through a canal to Lake Thun in the years 1711 to 1714. This exceedingly enterprising construction, for that time, can be described as the forerunner of Swiss river training.

How did these men hit upon this idea? To begin with it should be mentioned that according to folk-lore in the middle ages the monks from Interlaken, diverted the river Lütschine (which originally flowed from Interlaken into the mouth of the river Aare) to Lake Brienz. As a consequence the Lütschine deposited its flood and bed-loads into the lake, and its original alluvial fan, the so-called Bödeli, could be put into use. Thus already this middle ages river training project served both as flood protection and for land reclamation. Despite investigations, nothing reliable has become known to the author about

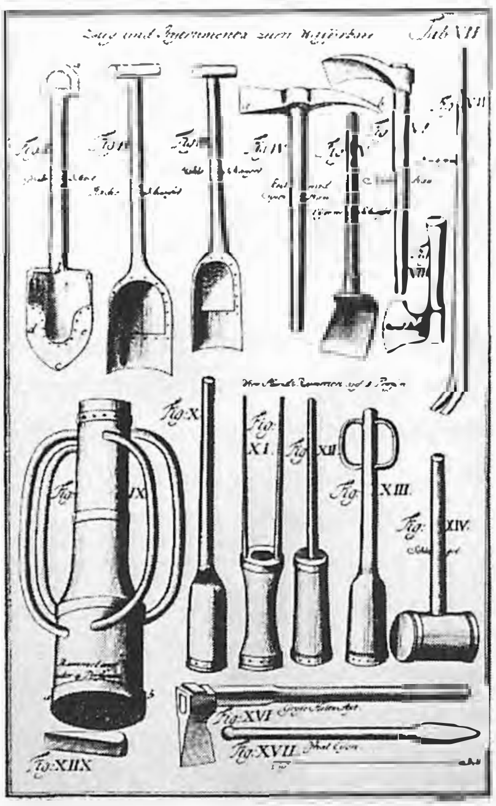


Illustration 11: *Work implements: "Tools and instruments for hydraulic engineering", according to Leupold 1724.*

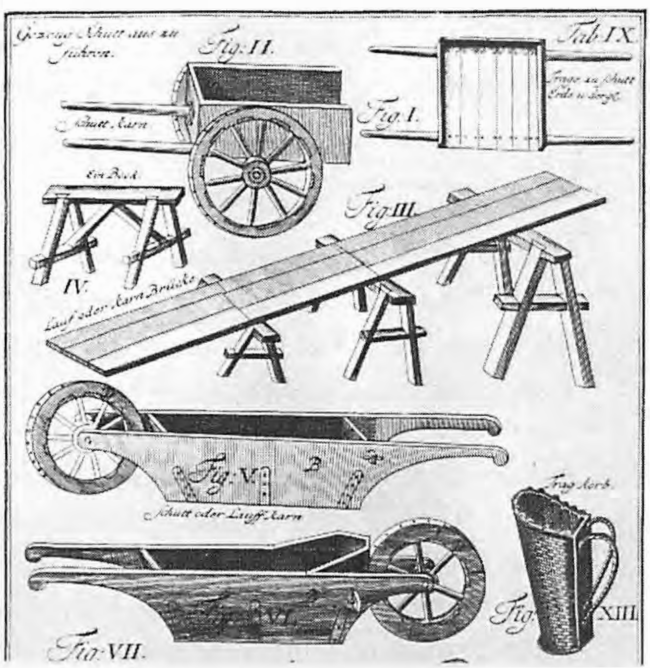


Illustration 12: *Methods of transport: "Implements used for the excavation of rubble from rivers", from Leupold 1724.*

the project and its execution. Yet it is certain that the actual or alleged diversion of the river Lütschine to the state of Bern and especially to the Oberland was intentional and provoked imitation even centuries later. The appeal in 1807 by Hans Conrad Escher and the dean of Bern, for the training of the Linth river, also makes express reference to it (see Section 3).

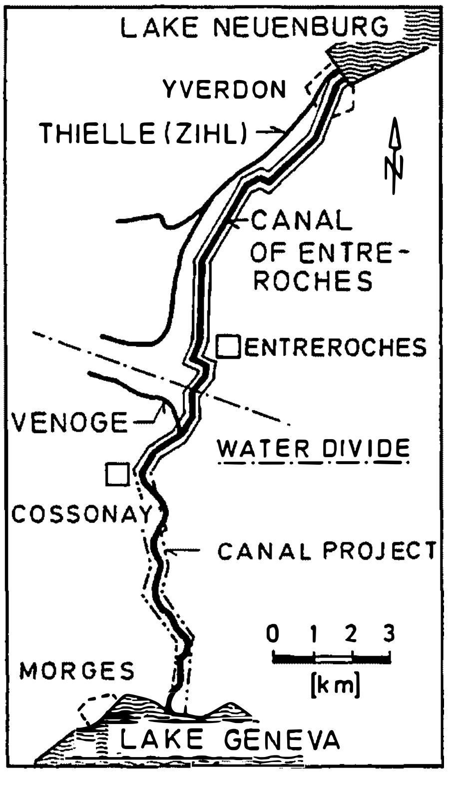


Illustration 13:
The Entreroches canal, constructed 1638-1664.

The lords of Bern were made aware of yet another experiment dealing with hydraulic engineering: the Entreroches canal was dug in their province between 1638 and 1664. The purpose of this canal was principally to provide a water-way rather than protection against floods: it was to make a connection about 36 km long between the Neuenburger lake and Lake Geneva, and in doing so, surmount the European watershed between the Rhine catchment area and that of the Rhone. The license was endorsed by a Dutch, Bernese and Genevan financial syndicate. The interest of the Dutch resulted from their quest for a route to the ports of the Middle East, which avoided the sea route via Gibraltar (thus by-passing belligerent Belgium and Spain). The administration of projects and construction was therefore initially taken over by a Huguenot in the service of the Dutch, Elie Gouret-du Plessis. He also brought water-engineering technicians and trades-people from Holland for the construction of locks and barques. It was in this manner that some knowledge of the art of Dutch hydraulic structures was imported to Switzerland.

At first the construction work progressed uninterrupted; the first 16 km from the Orbe plain to Entreroches were completed in two years. For the first 8 km a dyke was constructed along the navigable Zihl Creek and the Orbe-plain was excavated for the other 8 km. The standard profile consisted of a trapezoidal cross-section of 2.5 m in depth, 3 m bottom width and 5 m surface width. Then came the watershed itself, in mountainous terrain, where the canal had to be walled up in parts. The ascent to the watershed involved a gain in height of 18 m and consequently, the construction of only a few locks.

Illustration 14:
Elie Gouret, constructor of the Entreroches canal.

Contemporary technology meant that 47 locks had to be planned for the descent along the Venoge creek to Lake Geneva lying 80 m below. The stretch of watershed and the descent were thus technically sophisticated and extremely costly. The difficulties increased, eventually bringing construction to a standstill. Within eight years the 6 km stretch as far as Cossonay had been completed, then, around 1648 the consortium ran out of money. In 1664 it was exonerated by Bern from the duty of continuing the work: the plan to construct a trans-Swiss waterway of European importance failed as a consequence.

What remained was a canal with only regional significance. The stretch from Cossonay to Entreroches was soon put out of action. However, the 16 km stretch from Entreroches to Lake Neuenburg was used until 1829, i.e. for 180 years. It served especially for the transport of wine and salt from west Switzerland via the Neuenburg and Biel lakes as well as the river Aare to Bern and other localities, for example to Solothurn.

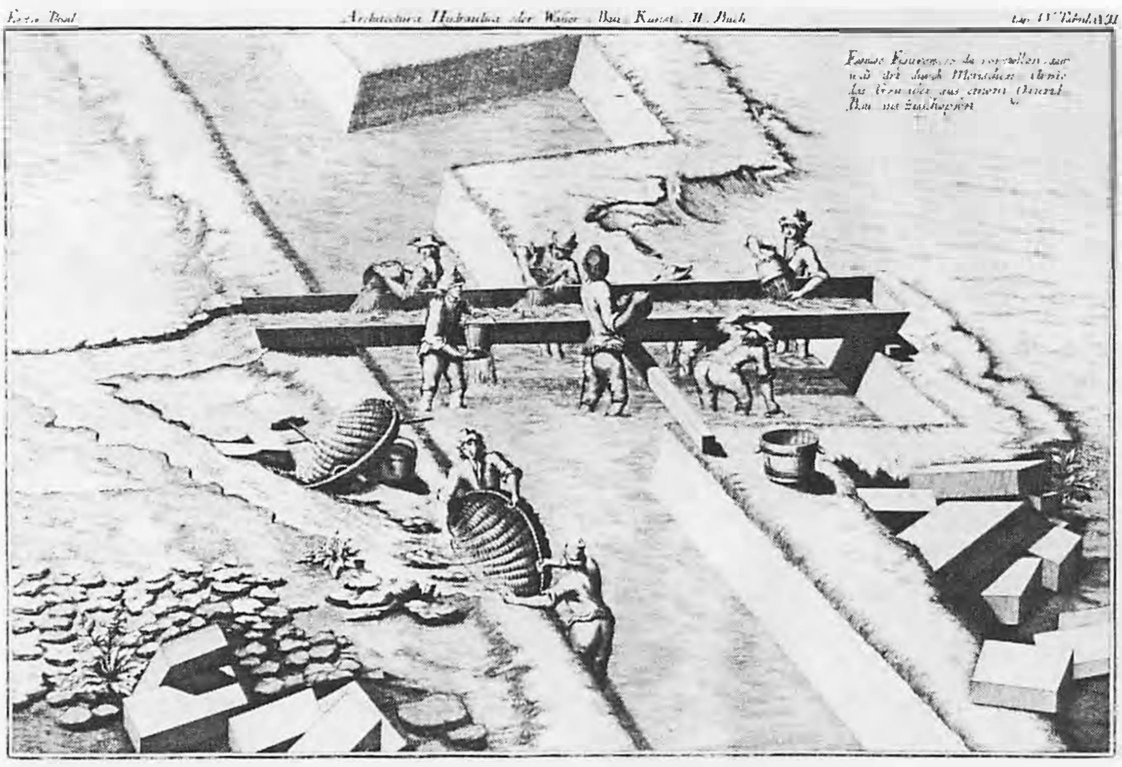


Illustration 15: *Water control: "... scooping water out of a substructure by hand", according to Bélidor, 1742.*

Getting back to the training of the Kander river! Originally the Kander flowed past Lake Thun and into the Aare approximately 4 km downstream from Thun. The Zulg joined it from the opposite direction. The Zulg as well as the Kander carried down large amounts of gravel during floods and in so doing dammed the river Aare. The result was frequent flooding in the bordering plains, in Thun and the area around Lake Thun. It is therefore no wonder that the inhabitants of these areas turned to the lords of Bern for help. As early as 1670 (the author follows essentially the explanations by Bachmann, 1983) a plan was proposed to bisect the range of hills at Strättligen and to divert the Kander river into Lake Thun.

The lords of Bern, the rulers of this large town-state, however, had other problems to attend to first. When the communities situated alongside the river Aare (who were afflicted by renewed flooding) begged for the diversion of the river Kander in 1698 and offered both money and workers for the realisation of the project, the lords of Bern appointed a committee to promote the matter. At the same time as the committee was appointed in 1698, opposition arose in the town of Thun and other surrounding areas.

Nevertheless, the principle decision supported by the planning work of the committee of 1700, was made in favour of the diversion of the Kander River. The corresponding decision to build was made in 1711. The execution of the work became the responsibility of a newly formed Kander directorship. Planning and supervision of construction was to be undertaken by the surveyor and artillery lieutenant, Samuel Bodmer. He devised a plan for river training with two connecting components: an open cutting of the Strättligen hill for the diversion of the Kander into Lake Thun; and a canal for the Aare, from Thun to as far as Uttigen (which lay about 7 km downstream), for the purpose of enlarging the Lake Thun outlet.

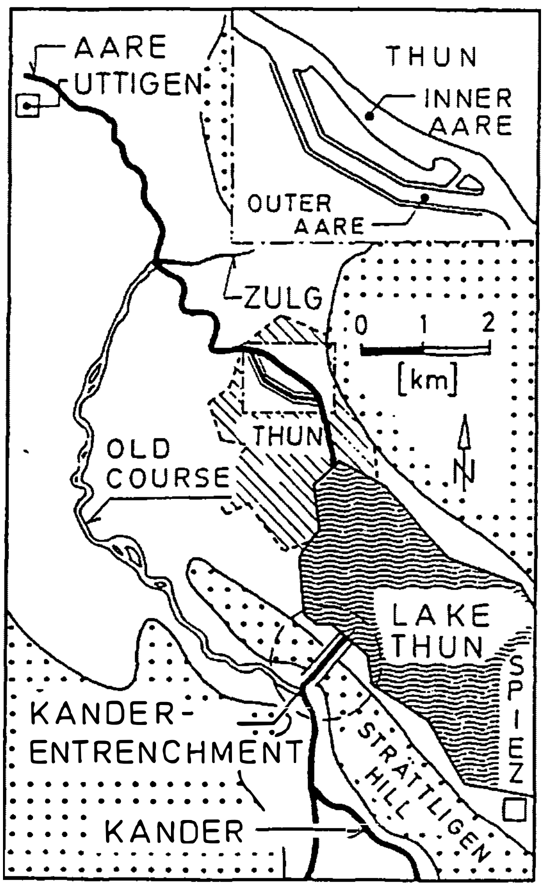


Illustration 16:
Training of the Kander River 1711-1714

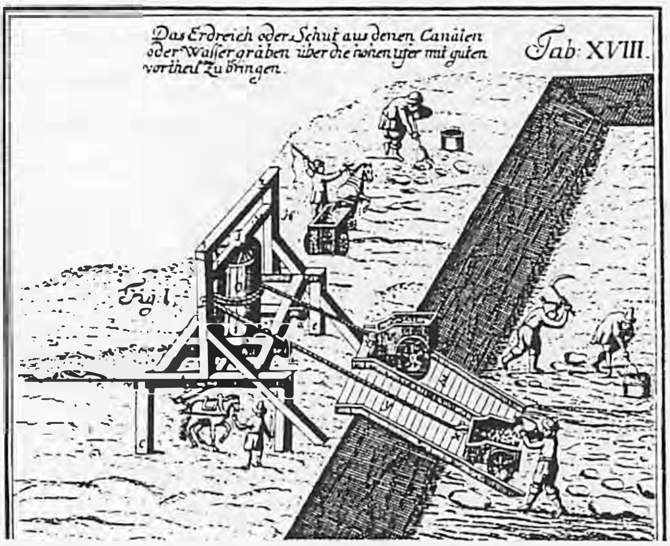


Illustration 17: *Excavation. Suggestion for the position of a cable car : "To carry the earth or rubble from canals or water trenches over high banks to best advantage", according to Leupold, 1724.*

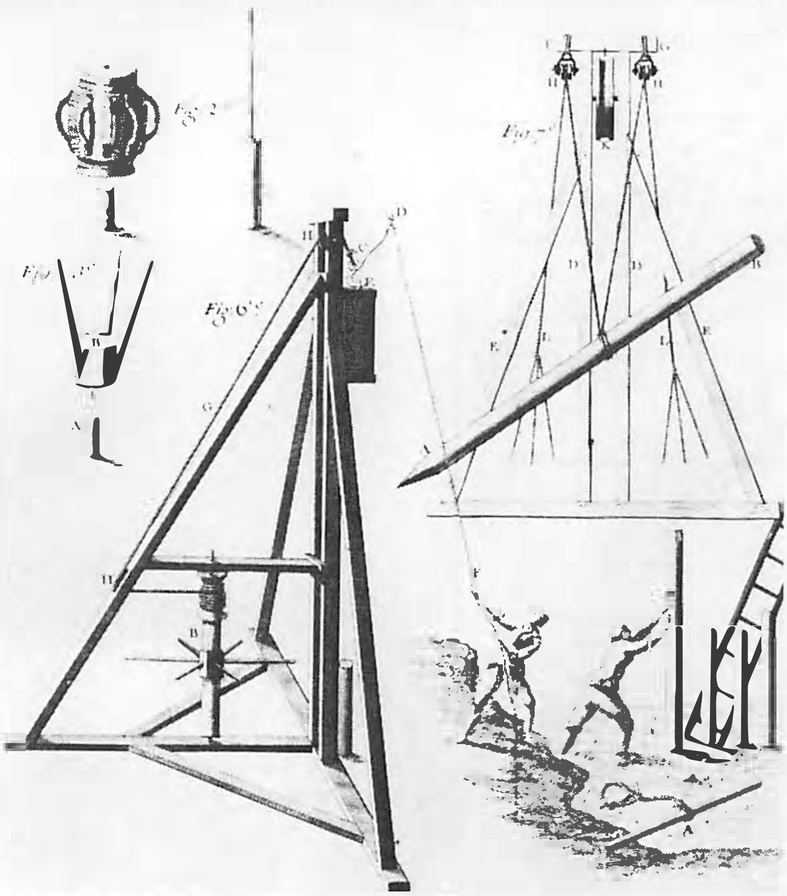


Illustration 18: *Ramming of stakes by hand or with a ramming trestle, according to Bélidor, 1737.*

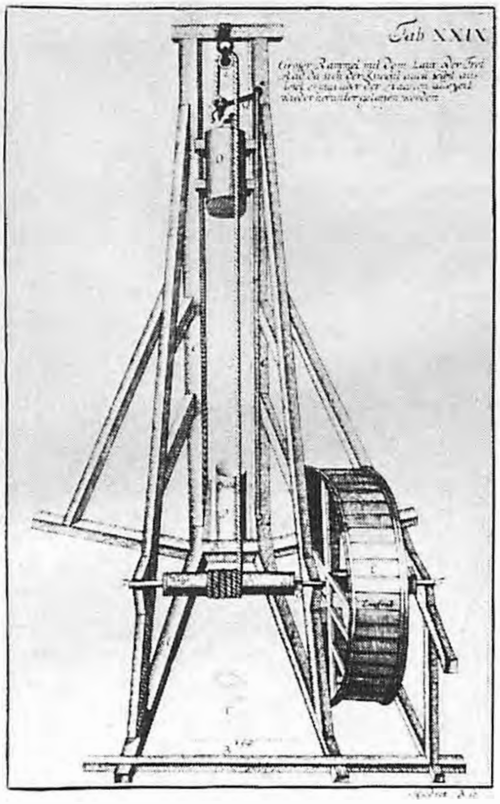


Illustration 19: *Apparatus for ramming: "Large rammer with trailing wheel, in which the weight is self-triggering but the hook must always be brought down again", from Leupold, 1724.*

To begin with, only the first component was completed. The construction began in April 1711, with the excavation of Strättligen hill from the Kander side along the proposed terrace. Bodmer's project was to make an incision approximately 950 m long, 85 m wide and with a maximum depth of 80 m; thus it required extensive earth movements. At 5 o'clock in the morning the labourers were led to the work place accompanied by a brass band. Work in those days lasted from 5 a.m. to 7 p.m. with meal breaks at 7-8 a.m. and 12-1 p.m.; thus it involved a 12 hour working day. Bodmer commanded four categories of workers:

- 12 to 24 foremen and special tradesmen

- 200 to 300 day labourers, hired and contracted by him. They were employed on a casual basis from May to October.

- 50 to 80 day labourers appointed and paid by the municipalities.

- 60 to 100 poor people, who came voluntarily, as well as beggars, tramps, the homeless and convicts, who were sent by the municipalities (among them many women and also children); with the exception of the convicts they earned a small recompense.

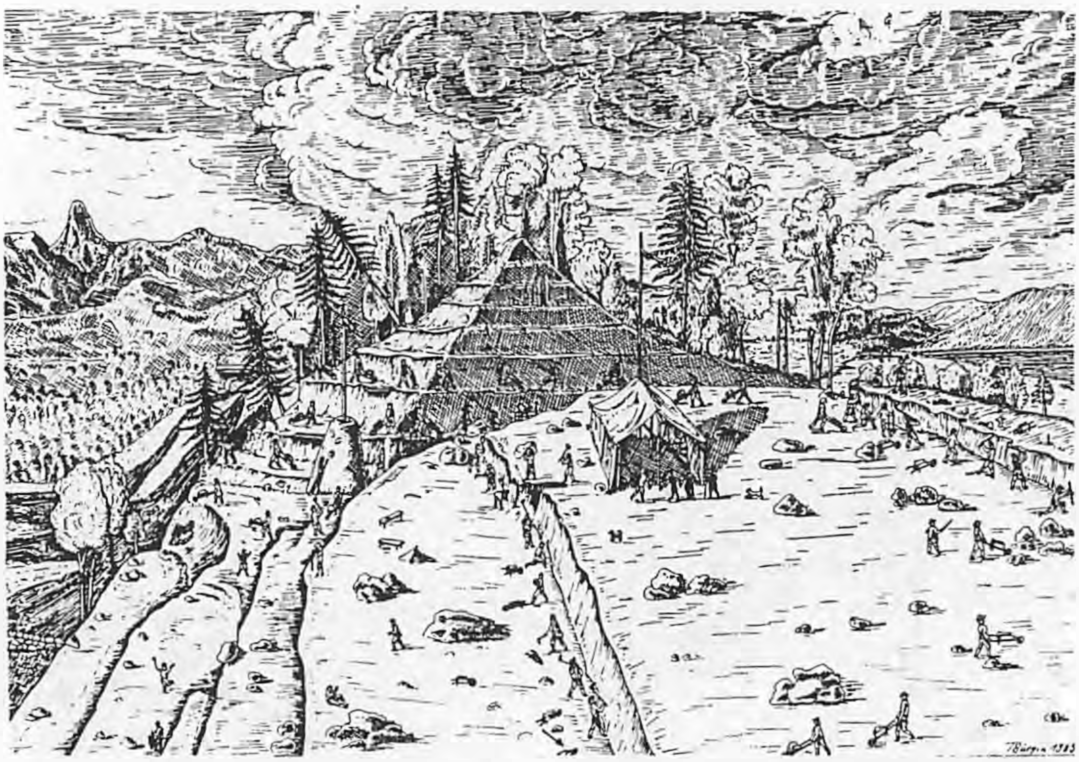


Illustration 20: *Training of the Kander River: Work on the cutting for the river Kander according to an oil painting of 1714 (historical museum in Bern), sketched by Toni Bürgin, 1985.*

It was soon proved that the difficulties of the excavation had been underestimated. The planned depth of incision was, as mentioned, approximately 80 m; this required excavation and embankment securing, which was difficult to achieve with the hand tools available at that time. For this reason the architect Samuel Jenner, a member of the Kander directorship, in December 1711 suggested an alteration to the project: the diversion of the Kander ought not to be an open canal all the way, but its middle segment should be a tunnel. However, at the beginning of 1712 the second Villmerger war broke out and interrupted the work. Bodmer had to dismiss a large proportion of his workforce and occupy himself with field fortifications on the Brünig pass. It was only in August 1712 that Jenner's plans for the works could be continued.

Jenner gave instructions to dig the tunnel from the Kander side as well as from the side of the lake. The profile 12 m in width and 4.5 m in height was quite considerable for the loose alluvial and moraine material, thus it was necessary to have a pilot tunnel with rounded timber supports. Since they had hoped for a better type of rock (Molasse-Conglomerate) certain difficulties as well as accidents began to occur with the tunnel excavation. However, by December 1713 a portion of the Kander waters could flow in the new direction on a trial basis. This portion was then regularly increased until a development took place which was completely out of the control of the Kander directorship.

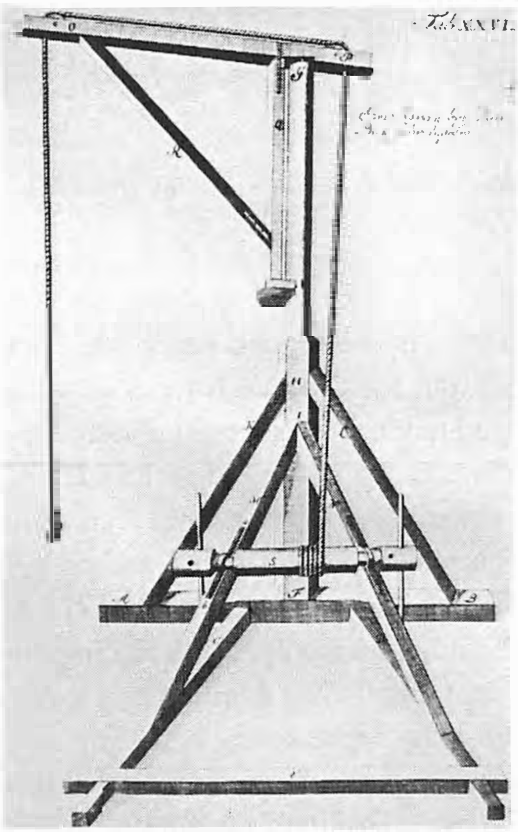


Illustration 21: *Construction crane: "A crane at the building site is very convenient", according to Leupold, 1725.*

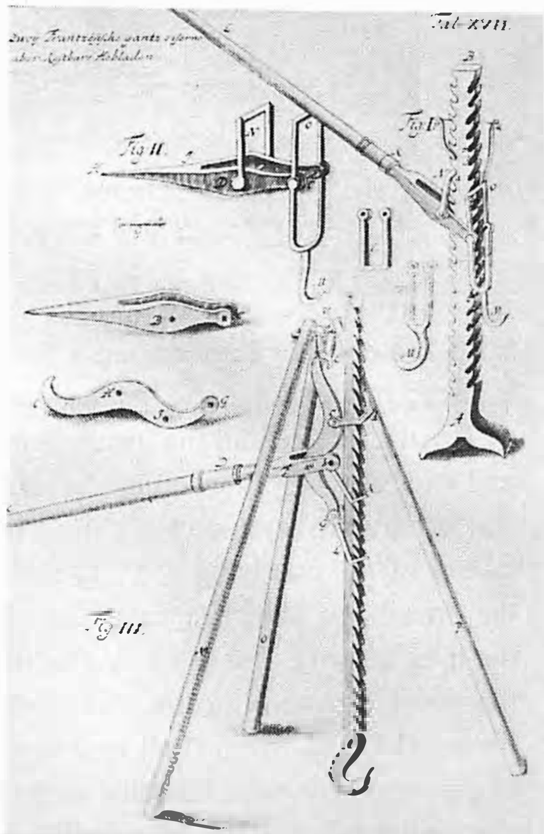


Illustration 22: *Manual jack: "Two French fully iron but also valuable jacks" according to Leupold, 1725.*

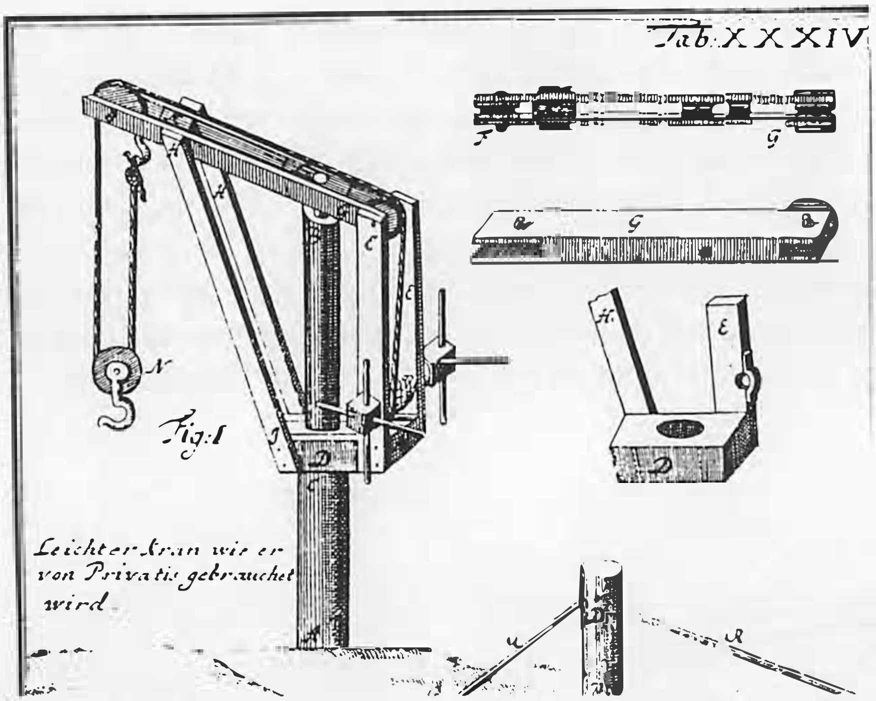


Illustration 23: *Construction crane: "Light crane as used by Private owners", according to Leupold, 1724.*

In its old bed the Kander had a fall of 0.5%. In the tunnel, which was several hundred metres long, the incline was 7%. Thus the diverted Kander developed a large drag force and the insufficiently lined tunnel was correspondingly eroded and widened. By the middle of 1714 it was carrying the entire Kander flow. The progressive erosion led ultimately to the collapse of the tunnel arch and the failure of the overlying soil. The accompanying rupture, sinking and noises in the Strättligen hill must have been frightening. A landslide in July 1714 took the lives of two Lords from Wattenwil. Right before the eyes of a visiting group they were dragged into the depths and swept away. The demand by Governor Emanuel Gross from Thun to divert the Kander immediately back into its old bed was to no avail. His plea came too late because the Kander had widened the tunnel quickly and irreversibly to a gorge whose bed eventually lay 25 m under the bed of the project and therefore also under the original bed of the Kander. The eroded material was carried into Lake Thun where, within two years, it formed a delta of more than half a square kilometer.

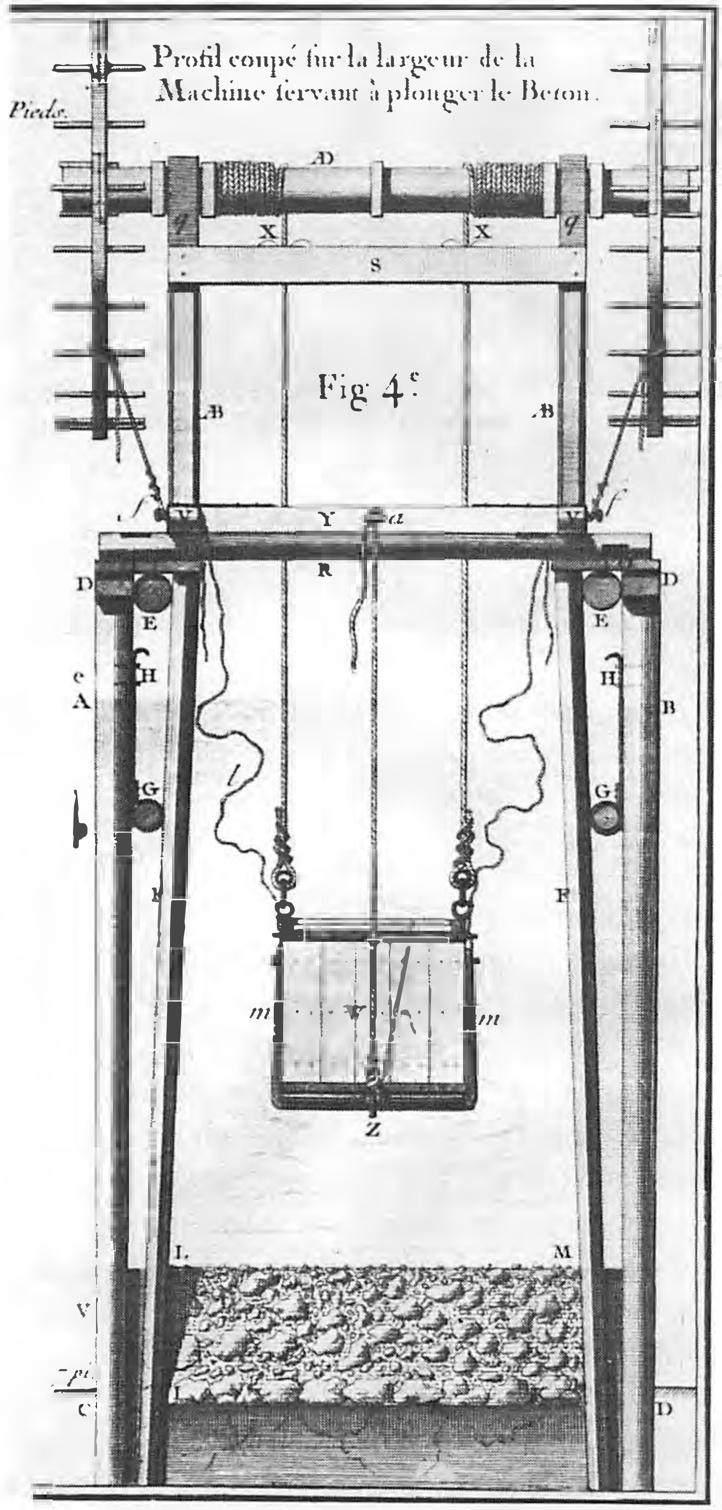


Illustration 24: *Under-water concreting: "Machine used for under-water concreting", according to Bélidor, 1737.*

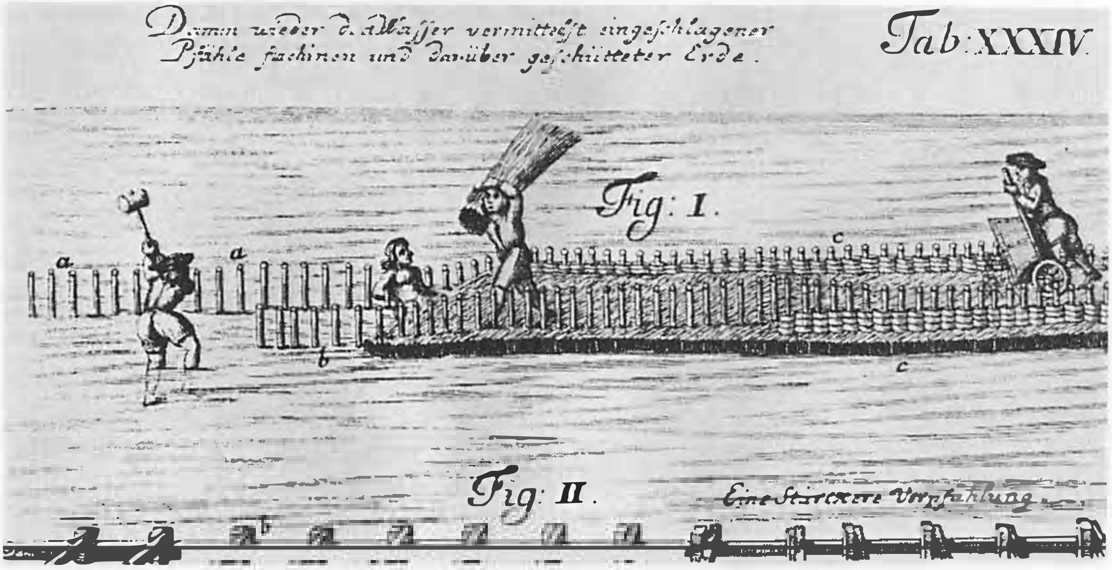


Illustration 25: *Dam construction: "Damming the water-flow by means of rammed stakes, fashines and earth poured over the top", according to Leupold, 1724.*

Since only the first component of Bodmer's plan had been realised - including the modifications brought about by nature - the first drawbacks soon became evident. The training of the Kander indeed protected the inhabitants living around the Aare river and the former banks of the Kander downstream from Thun, from catastrophic floods. To the inhabitants of Thun and other lakeside dwellers it brought, on the contrary, an increase in the inundation of banks, just as they had predicted and feared. Therefore the lords of Bern decided, as early as October 1716, to improve the outlet from Lake Thun into the Aare. That meant essentially the realisation of the second component proposed by Bodmer. Because this plan also pointed the way for later Swiss river training and especially for regulating the lakes, it should be briefly mentioned.

At the time of the diversion of the Kander, the river Aare in Thun consisted of the present day Inner Aare and also a city moat which branched south from it and then flowed into it again downstream. Both water ways had weirs at their upper end. The weirs served several mills and guaranteed a minimal water level for navigation in the lake. When water levels were low, only the weir on the Inner Aare overflowed, thus the Aare river flowed through the Inner Aare bed only. Only at high levels did the water from the Aare run in and through the city moat. During floods the total run-off capacity was far too small, and each time this caused flooding up to the first storey of the low-lying houses in Thun. Therefore the government bought the mills for a large sum of money (according to Nussbaum 1925) and had the weirs, which hindered the run-off, removed. The result was an increase in the flow of the Aare through the town. But now, banks and bridge piles also began to be eroded. Before long, the Sinne bridge, together with some houses that had been undermined, collapsed into the Aare. The actual aim of the project - the prevention of flooding - was not achieved. Further precautions were now occasioned with a project worked out by Governor Emanuel Gross and approved in 1720 (Neumann, 1979). This involved the prevention of the inundation of Thun and the villages around the

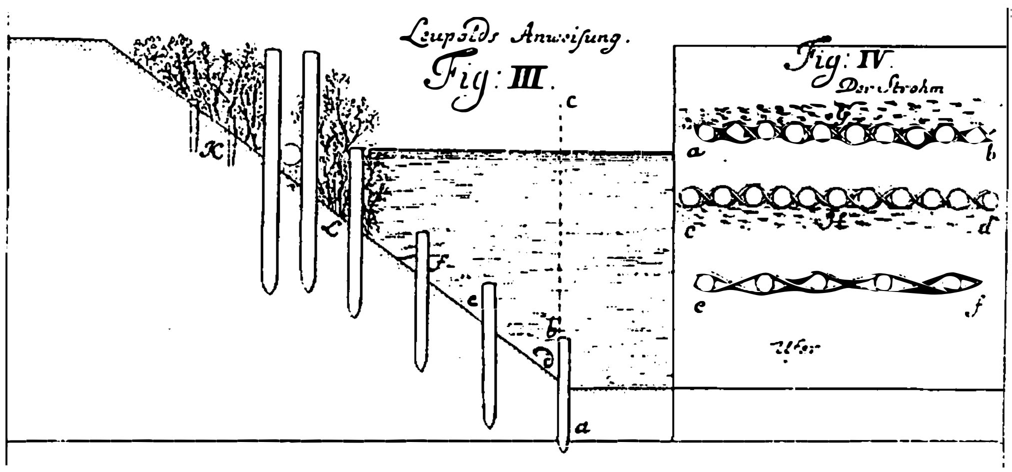


Illustration 26: *Bank protection with wicker work: "Leupold's instruction", 1724*

lake. First, the town moat was extended and deepened; it was named the New or Outer Aare. It can be considered as the forerunner of today's modern flood discharge canals, for example, the one being put into effect on the Danube in Vienna. Second, the bed of the river Aare from Thun to Uttigen was trained, i.e. straightened. Third, the removed weirs were replaced by so-called sluices which are, in effect, adjustable weirs. At high water levels they served to permit free flow of the Aare river in order to keep the lake safely below danger level. Otherwise (at mid or low water level) they served to keep the lake at normal levels.

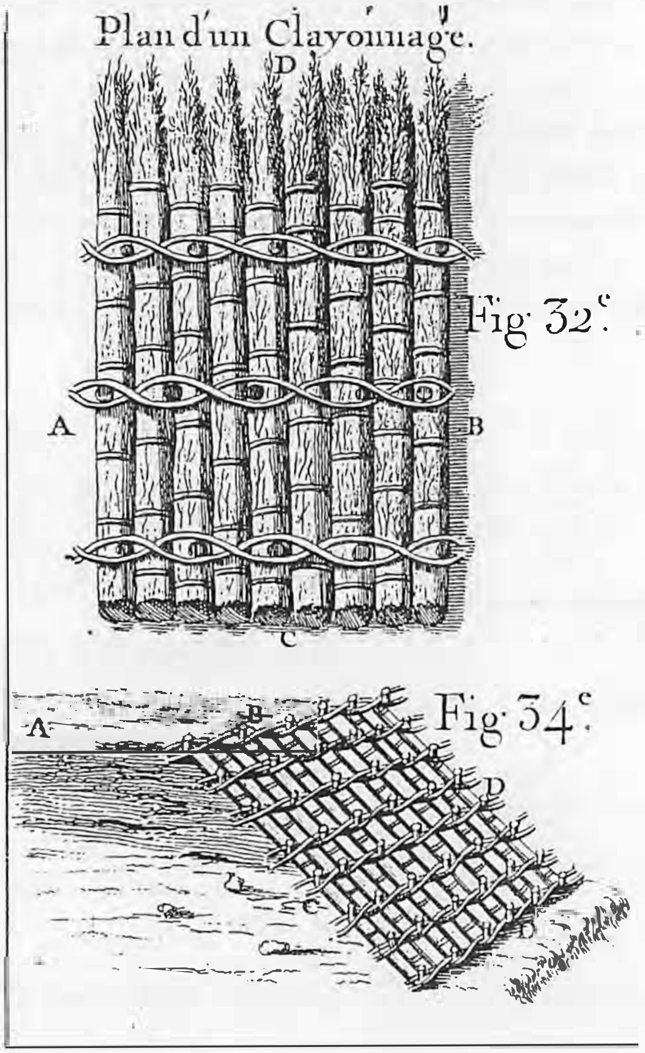


Illustration 27:
Bank protection with fashines and wickerwork, according to Bélidor, 1737.

The sluice in the Outer Aare, approximately 60 m long, was set up in 1726 by the carpenter Michael Maurer of Trimstein. It contained ten gates 4.7 to 5.7 m wide, two of which served the purpose of navigation for shipping. At about the same time the sluices in the Inner Aare were constructed with five gates including windlass operation (Neumann 1979). Later both sluices were renewed, the one on the Inner Aare as early as 1788. It was relocated in a new position under the Sinne Bridge. The one on the Outer Aare was renewed in 1818 according to the plans of Johann Gottfried Tulla and Hans Conrad Escher - the team which had been successful in the training of the Linth River.

The completion of the works that had begun with the Kander River training, could only be accomplished after the training of the Aare river from Thun to Uttigen in 1782 to 1792 and 1871 to 1873 (Schweizerisches Ober-Bauinspektorat, 1916).

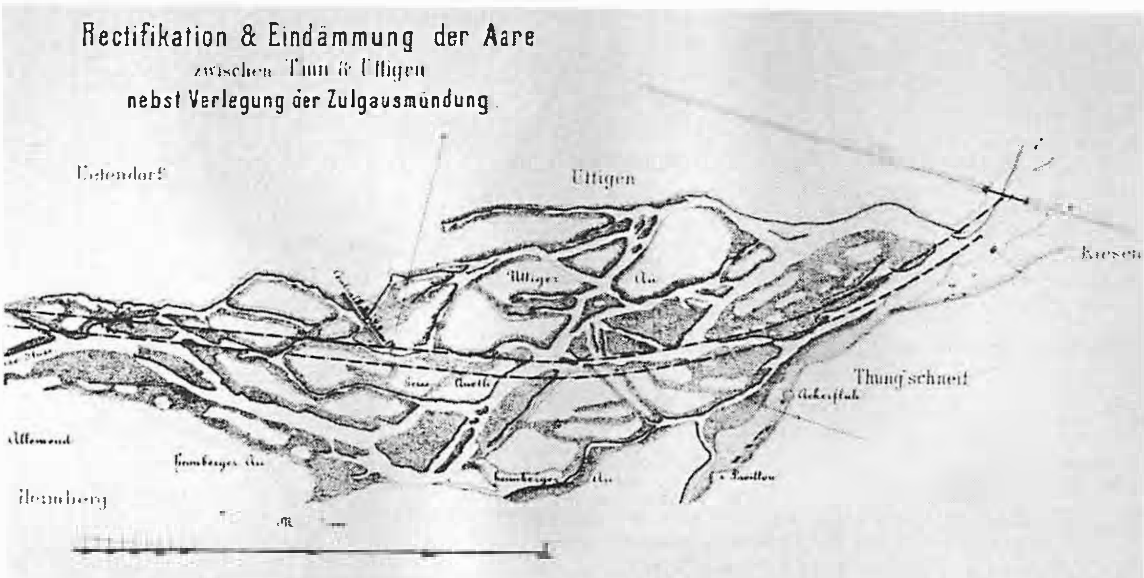


Illustration 28: *Training of the Aare: "Rectification and stop-banking of the Aare between Thun and Uttigen, including shifting the mouth of the Zulg", according to Hess, about 1875.*

3. Training of the Linth river (1807-1816)

The increased amount of flooding in the 18th century, and especially the emergencies of 1762 and 1784, brought vast difficulties upon the population along the river Linth and Lake Walen, all the more so as the times were adverse in any case. A truly sad picture of it is given by Becker (1910):

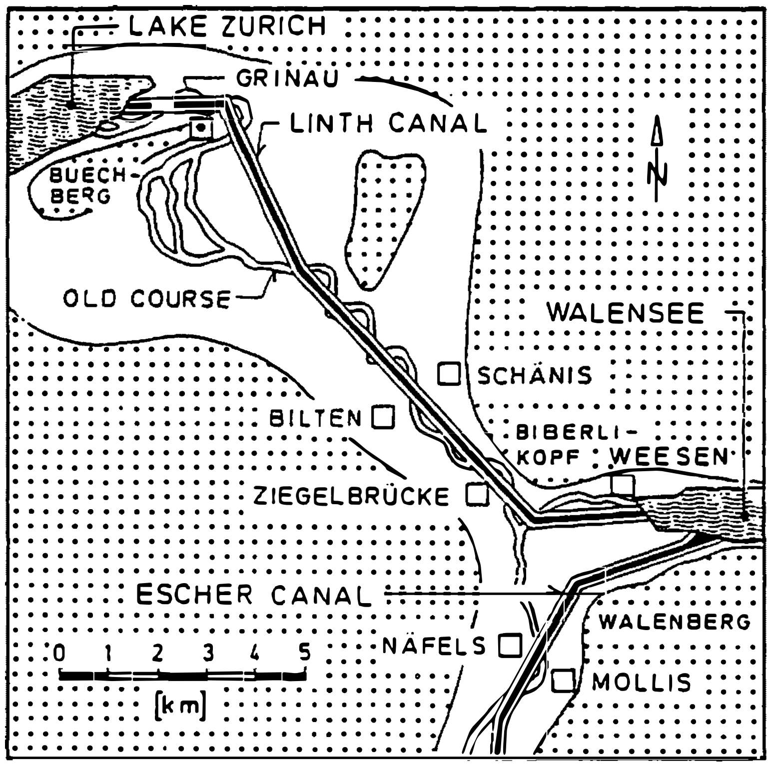


Illustration 29: *Training of the Linth River 1807-1816*

> *"Along with the horrific devastation due to flooding in the Linth valley (which amounted to millions in damage), came a decline in industry with long term unemployment. This was especially pressing for the inhabitants who were reliant upon the new income. In addition to this blow there was an outbreak of disease in the potato crop. The remnants were consumed by the starving hoards of foreign armies who marched through the land in 1798 and 1799. The misery was so great that in certain communities people led their children into the pastures to feed them on grass and roots. They also gave away children in large numbers for adoption in other areas in Switzerland and in Swabia.*

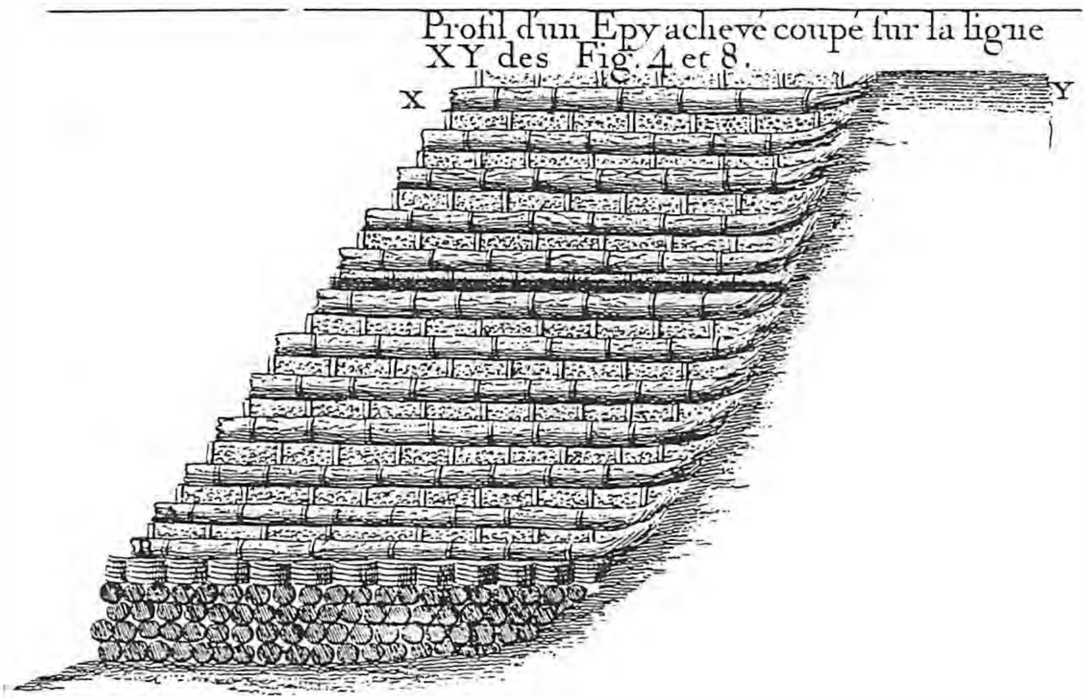


Illustration 30: *Fashine spurs or groynes, cross-section according to Bélidor 1737.*

"From the Gross valley alone, that is, the Linth valley upwards from Schwanden, 500 children were given away.... The conditions in the lowland area were even more terrible. In addition to the already devastated ground, the air, which was still good in the valleys at least, was polluted and everything was rotting. A single swamp stretched from Näfels and Oberurnen to Lake Walen and from there to Lake Zurich and further up into the Seez valley. The Gräplang castle, which stood on a high rock at Flums, had to be abandoned due to the rising fever-ridden vapours. The cold fever, also putrid fever - as it was called - that is, malaria in its worst form, lodged itself, taking its toll on the health and lives of the population.

"The inhabitants of the lowlands died a decade earlier than those of the highlands. ... The entire valley floor, formerly a delightful meadow terrain with maize and potato fields, had become unproductive and was abandoned. Death loomed over the area. A population of about 16,000 headed towards physical and moral decline. Switzerland had never before seen such misery, the terrible circumstances lasting not for years but through the course of generations."

It is no wonder that this misery attracted widespread attention. Already from 1738 the diet of Glarus had concerned itself in earnest with questions of draining the swamps, without however, occasioning or achieving more than basic piecemeal work. Then the call for a drastic solution became increasingly louder and finally produced an extremely audacious plan which first appeared in the chronicle of 1774 by Pastor Christoph Trümpy:

> *"People have often talked of suggestions as to how to reduce the level of Lake Walen and to reclaim the lower lake flats from swamp. An intelligent mathematician is supposed to have found it feasible to lead the Linth along the foot of the Walen mountain, into the lake and then out through the Maag river and several canals, providing adequate drainage in the process. Such a design alone has so many difficulties and obstacles that we consider it to be a dream".*

Who was this mathematician, whose plan was to be realized a generation later? But still the plan appeared to be a dream, still the time was not right; the evil spread further and occasioned the confederate diet of 1783 to commission the Bernese captain Andreas Lanz to draught some plans.

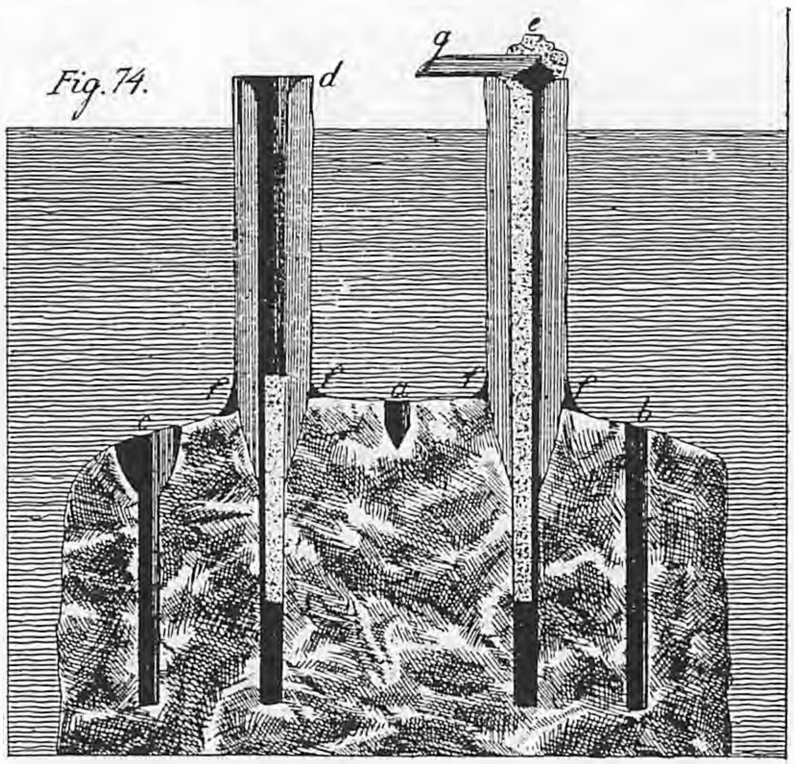


Illustration 31: *Underwater blasting. Arrangement of the explosive and igniting charges in the drilling hole, according to Gilly and Eytelwein, 1802.*

Within a year Lanz had worked out four variants. He described the plan to divert the Linth, in a new bed, directly into Lake Walen as the best of the four, because it alone promised long-term relief. The preliminary estimate of costs, however, was so high that the confederate diet was at first very reluctant to put the project into action. Then in 1792 and 1793 the Helvetican Society adopted the matter; they found in 26-year-old Hans Conrad Escher of Zurich an extremely attentive and active member.

Illustration 32: *"Medium high" lake level in Weesen. Drawing by H.C. Escher, copper etching by J H Meyer 1809 (central library in Zurich).*

As a consequence Escher travelled several times to the Linth and Lake Walen area and in 1796 reported on circumstances there; he fully supported Lanz's plan and presented a review on it to the last diet of the old confederation. This system of government was then superseded by new times; the necessary help for the Linth people failed to appear, even though many letters of complaint were submitted.

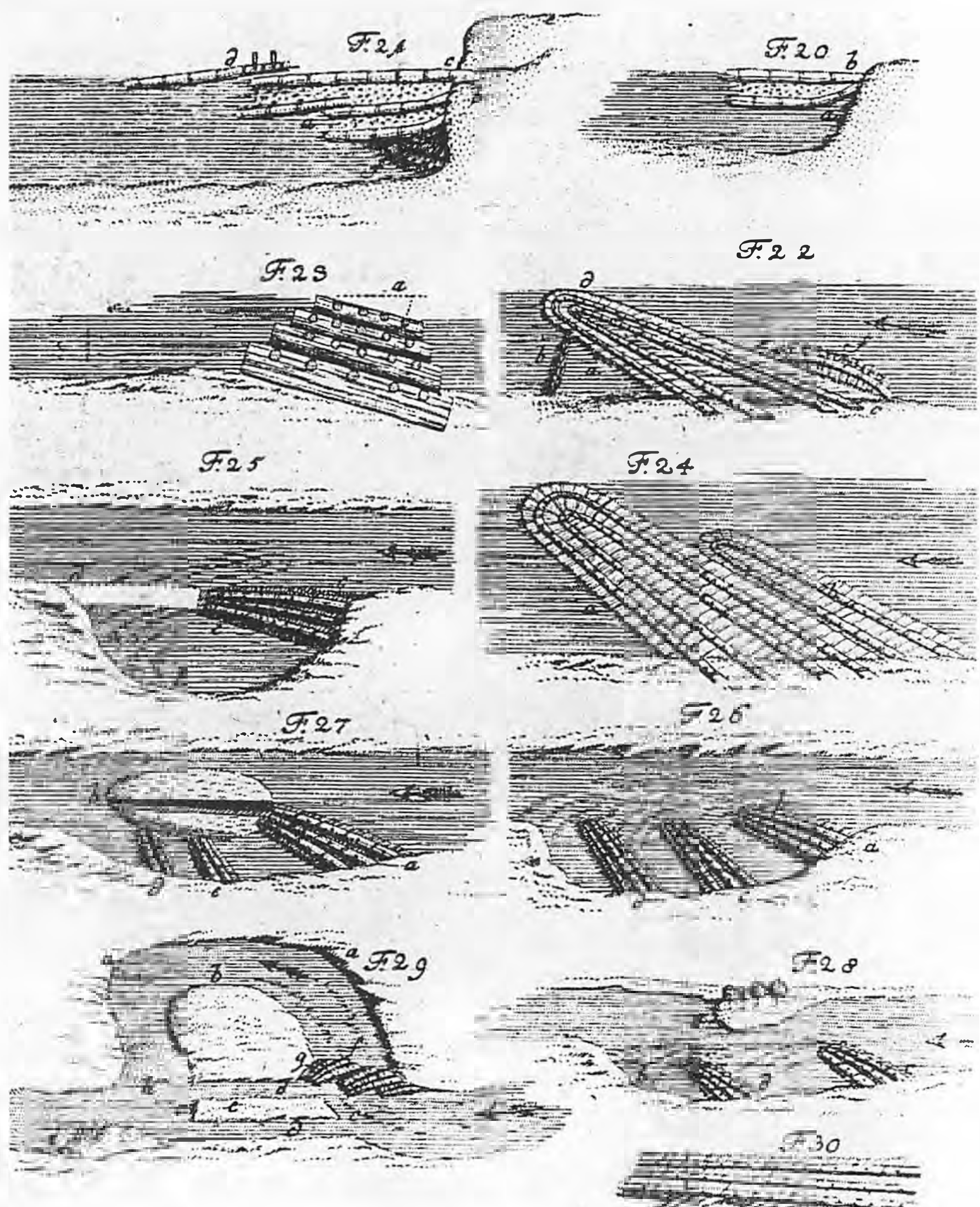


Illustration 33: *Insertion of spurs and groynes according to Silberschlag, 1766.*

However, at least private donations were fed into the disaster areas; for example, during his research the present author came across a paper published by Deacon Leonhard Tschudi from Schwanden in February 1800, entitled: *"Catalogue and Accounts of the Voluntary Taxes and Donations of Noble Swiss for the Support of Suffering Mankind in the Linth Canton".* It records the donations, especially by many communities in the Bern canton, in money terms and in measures of grain, oats, dried fruit, dried potatoes and in pounds of bacon fat, cheese, etc.

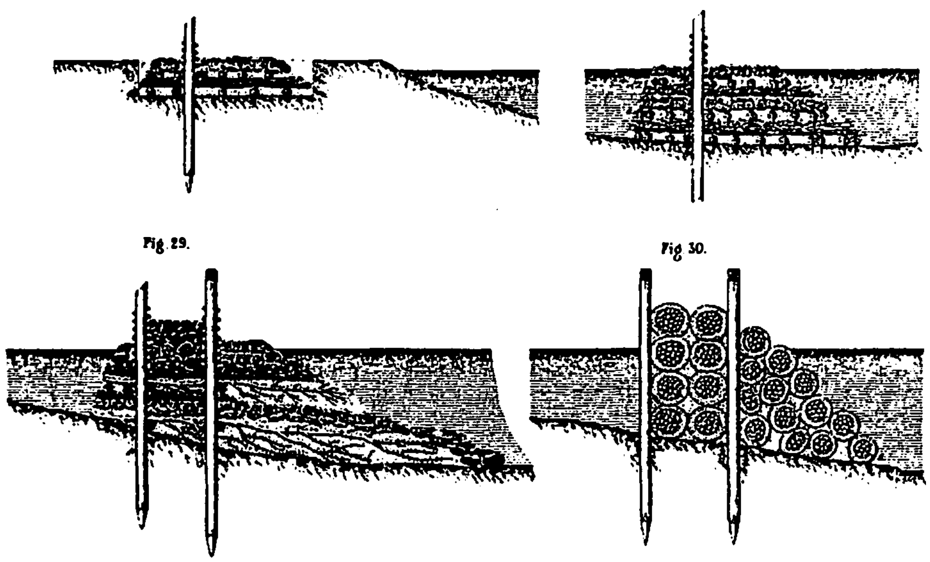


Illustration 34: *Empennage: "Detail of fashine work with young spruces or the tops of old spruces (so-called stakes) according to Bauernfeind, 1866.*

It was only the Mediation constitution of 1803 that gave back to the new confederation the necessary peace and a minimal amount of freedom for action. With the perpetual misery before their eyes, the confederate diet in 1803 appointed a first commission, who again recommended the employment of Lanz's plan, and in 1804 a second, who, under the leadership of Escher, worked out a more refined project with estimates of costs, and plans for financing. In 1805, the decision was taken to proceed with the construction and a Linth supervision committee was appointed, with Escher as President, the councillor Conrad Schindler from Glarus and the architect Osterried from Bern as members; Captain Lanz had died in 1803. The 1805 border occupation (necessary because of the international situation) and the 1806 flooding catastrophes in inner Switzerland, including the Goldauer landslide which claimed 400 victims, occupied the public to such an extent that the start of construction on the Linth operation had to be delayed. In 1807, however, those responsible proceeded to act - and at the forefront was the President of Switzerland, Reinhard from Zurich.

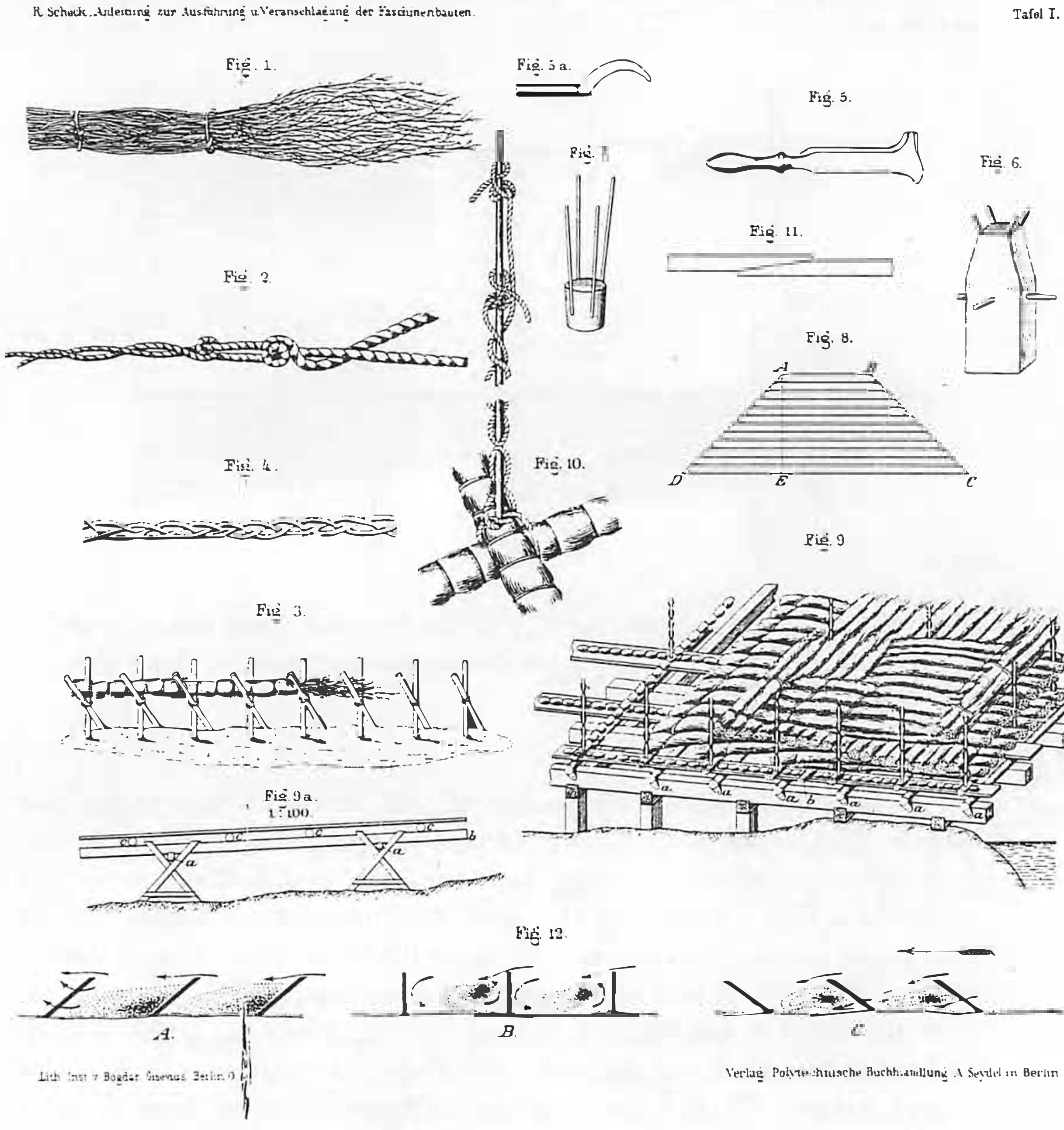


Illustration 35: *Positioning of fashines from: "Instructions for the Execution and Establishment of Fashine Construction" by Scheck, 1885.*

Because the confederate diet had practically no money at its disposal, the finance was secured by shares; thus, the first corporation of the new confederation was established. The advertising papers, written by Escher and the Dean of Bern bore the title *"Summons to the Swiss Nation for the rescue of the inhabitants of the banks of Lake Walen and of the Lower Linth valley overthrown by misery due to the development of swamps"*.

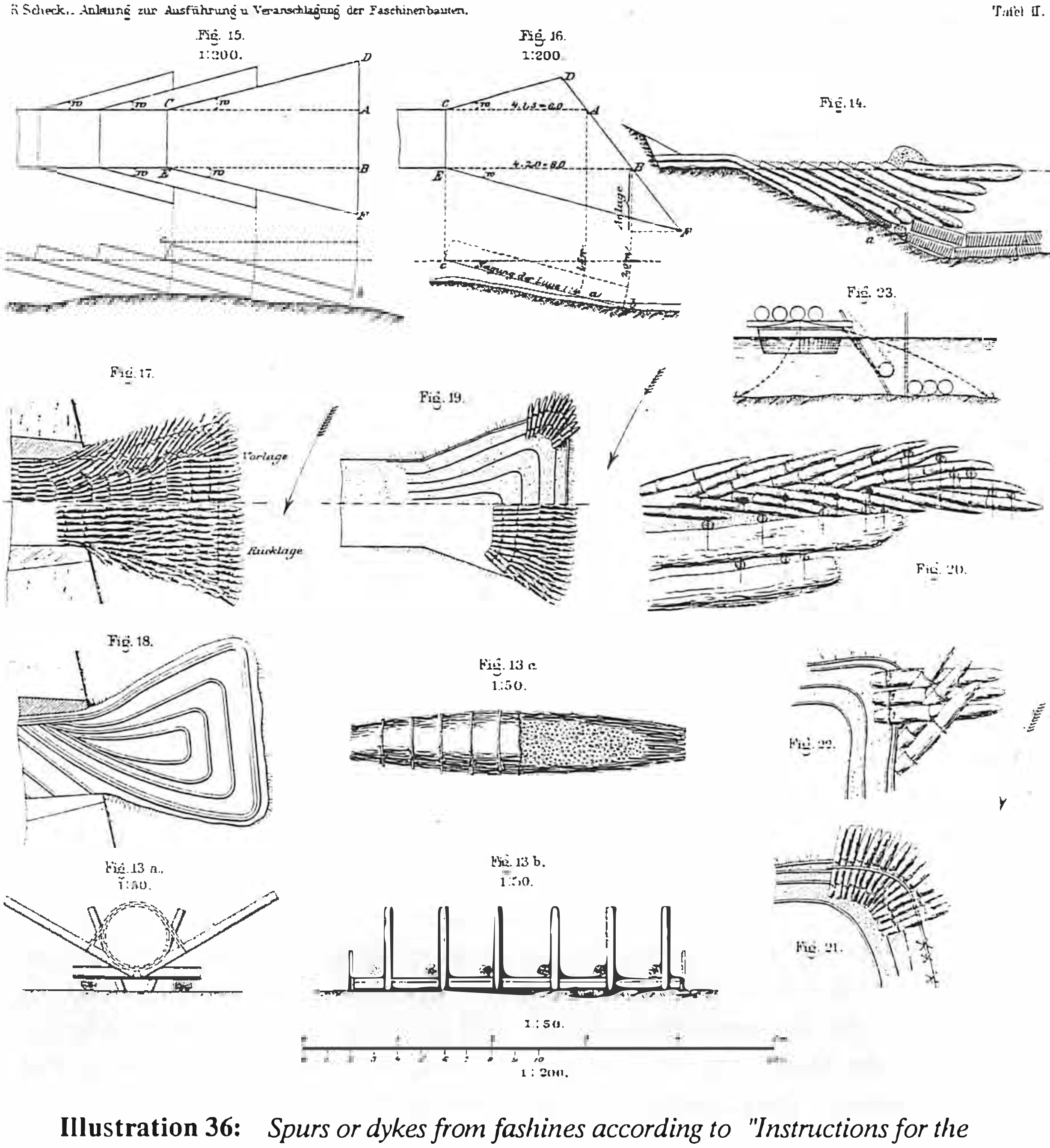


Illustration 36: *Spurs or dykes from fashines according to "Instructions for the Execution and Establishment of Fashine Construction" by Scheck, 1885.*

This was first circulated at the beginning of 1807. According to Thürer (1966), it is one of the most remarkable documents of Swiss history and connects *"the clarity of an expert opinion with the call of the heart. As examples, it evokes the encouraging experiences from the Bernese Oberland, with the diversion of the Lütschine into Lake Brienz, and later of the Kander into Lake Thun. These preserved the Interlaken and Thun areas from becoming swamps, which happened in the Linth area"*. And at the end it turns to the fellow confederates of the time, with the words: *"Alone, still help is there! It is in your hearts! Let us hurry to rescue you. That your sunken floor be freed from this sad slough - your contaminated air be purified - your descendants be preserved from the danger of a slow, but unavoidable ruin - this is the good deed which they request, which you cannot deny them"*. The response which the advertisement evoked surpassed all expectations. Within a few months, instead of the predicted 1600 shares at Fr. 200.-, more than 2000 were subscribed by cantons, corporations, municipalities and privately.

But who possessed the special knowledge for the Linth operation? As already mentioned in Section 1, the confederate committee appointed the Rhine dam inspector and, at that time Captain, Johann Gottfried Tulla from Baden as hydraulic engineer, that is, as project and construction manager. Twice he obtained a holiday from his employer, the grand Duke of Baden, in order to show his art and experience, firstly from September to November 1807 and then a few weeks in 1808. In this short time, he carried out the river hydraulic calculations for the essential parts that were to be trained. These were made on the basis of available land surveying measurements and on hydraulic measurements taken specially for this purpose. A contemporary, engineer and colonel Heinrich Pestalozzi (1852) and the later acting Linth engineer Gottlieb Heinrich Legler (1868), described these works in detail and confirmed that Tulla was a great master, both in the theory of river hydraulics and in the practise of river engineering. Besides, he was admirably supported by his co-worker, engineer Obrecht, who worked with him on the training of the Linth for five months of each of the years 1807 and 1808. It is quite remarkable how well informed Tulla was, even then, about the gravel transport of the rivers and how he gave the Mollis-Linth canal, later called the Escher canal, its dimensions. No wonder that the confederate diet of 1812 delivered to Tulla (who had in the meantime been promoted to Major), a ceremonial letter from the President of Switzerland. The following is a protocol excerpt from it (Zier 1970).

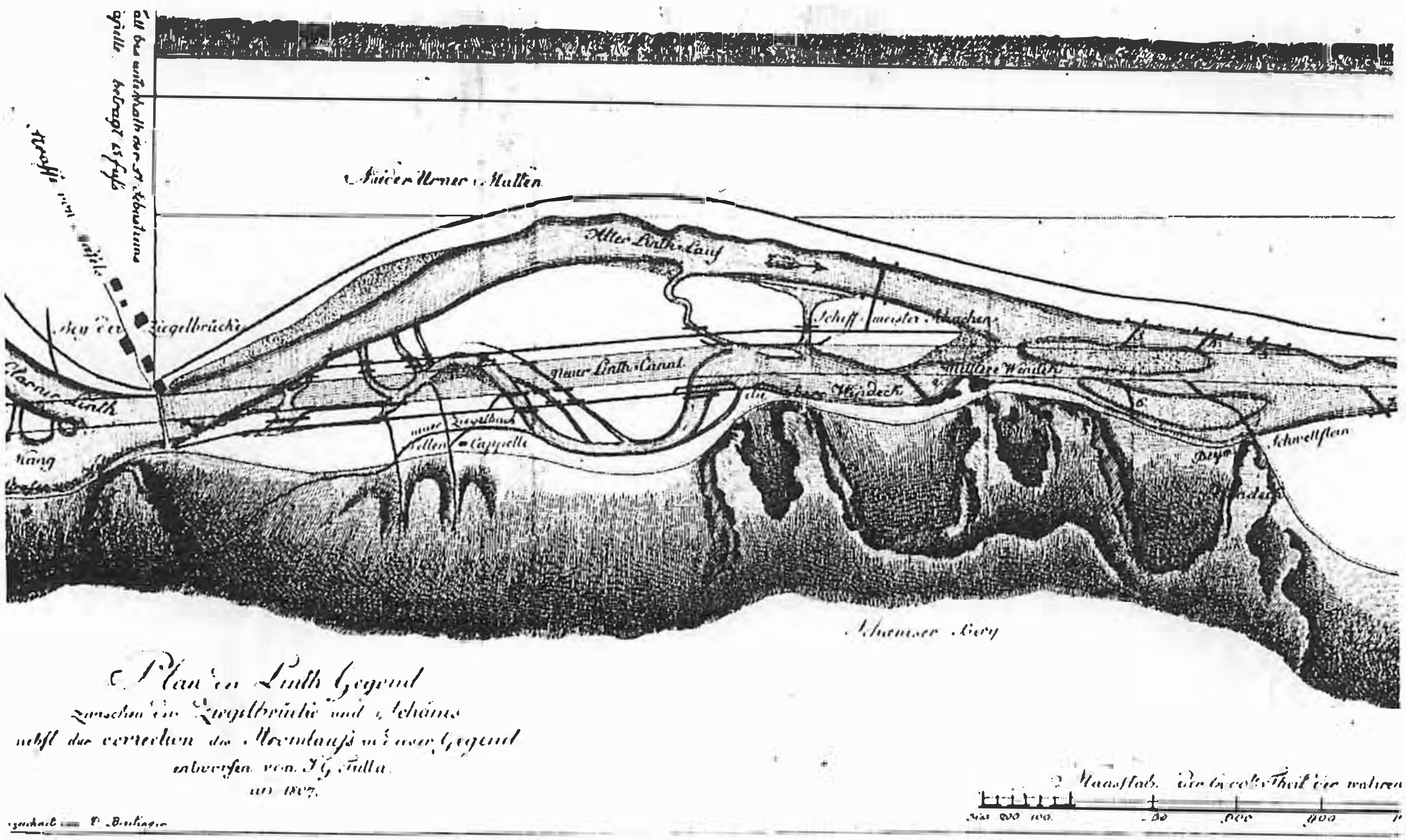


Illustration 37: *Training of the Linth River: "Plan of the Linth area between Ziegelbrücke and Schänis, together with the correction of the river flow in this area, sketched by J G Tulla, 1807".*

"His excellency the President of Switzerland is commissioned to announce, by a letter issued in the name of the confederate diet, to the grand-ducal Badic engineer-major Tulla and his assistant engineer Obrecht, the applause, satisfaction and respect which the representatives of the confederation harbour towards these men and who have the pleasure to inform them that they have been notified by the Linth supervision committee about the extensive and important contributions to the Linth training of these men of insight."

The fact that Tulla was available only for short periods compelled Escher, in spite of his other intensive work, to succeed Tulla and learn the techniques of hydraulics himself. Previously Escher had had no experience in hydraulic engineering. However his broad knowledge of science and his ability to grasp concepts easily enabled him, with the help of Tulla and Obrecht, to become acquainted with the job in only a few months. There is mention in the records of a letter from Tulla to Escher in February 1808, which recognised this success (Pestalozzi 1852). The letter speaks for the teacher as well as for the pupil. In any case, from 1808, Escher carried out all planning and marking out procedures practically alone. He shared the burden of construction management with his colleague Conrad Schindler from the supervision commission.

From 1807 the works on the Linth progressed swiftly. An excellent summary of the work in progress is given in the *"Report of the Commission for Investigation of the Linth Procedures to the Confederate Diet in the year 1810"*. Large sections of this report are reproduced here because it is easy to read and presents many interesting construction details with remarkable clarity.

"Let us be permitted to make you, most honourable lords, recall by way of a short representation, the condition of the Linth Valley which had occasioned the training of the Linth.

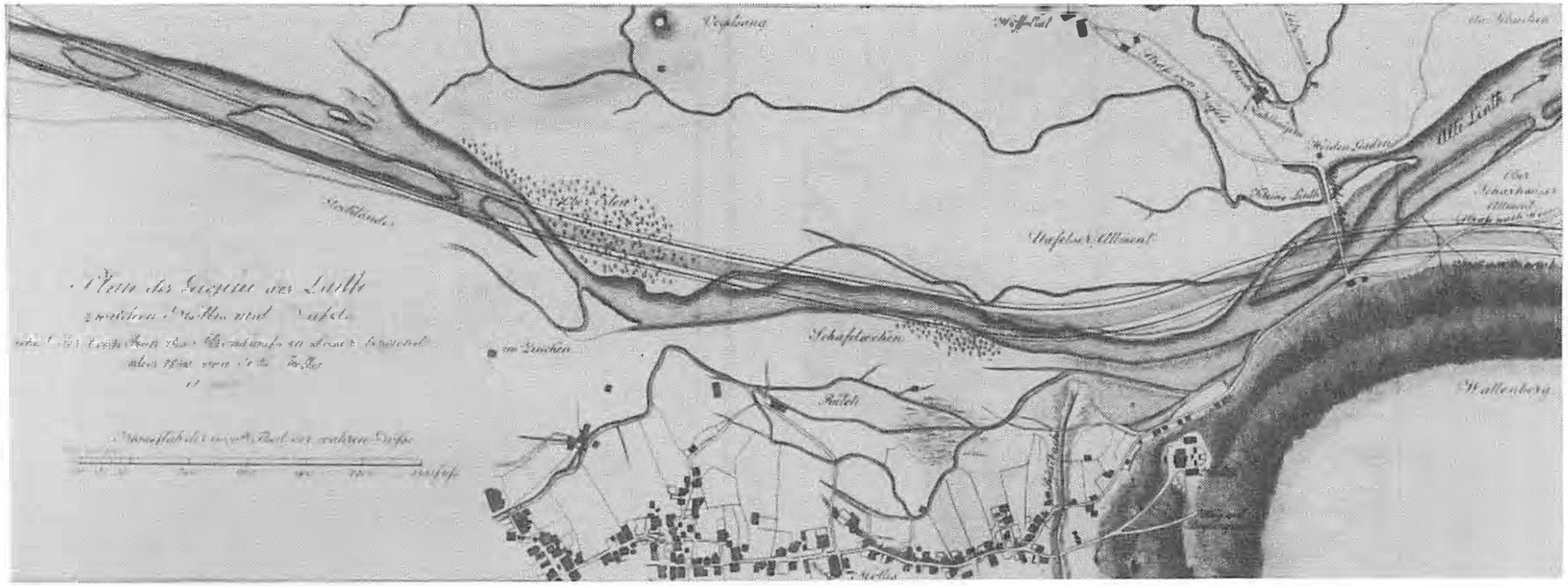


Illustration 38: *Training of the Linth River: "Plan of area of the Linth between Mollis and Näfels including the correction of the river flow in this area, sketched by G J Tulla, 1807.*

With the continuous outwash of sand and stones from the mountains of Glarus, the Linth bed was raised as far as its mouth into Lake Zurich. The stop banking partially protected against flooding but it could not prevent the river water, confined in the raised bed, from seeping through the ground to the lower plains of the Linth valley. At the same time, it hampered the draining of the mountain brooks. In this way the 900 hectare Schänis swamp was formed. At Ziegelbrücke where the river Maag, the outlet of Lake Walen, united with the Linth, the bed of the river had risen a full 16 feet within a period of 50 years. This often caused the lake discharge to be delayed and become swollen. The result was that often the water poured back into the lake when in fact there should have been a fall of 10 feet from the lake to Ziegelbrücke. Thus the elevation of the Linth bed lifted the water level of Lake Walen six feet. The consequences were: complete flooding of the plains adjacent to the lakes rendering the towns of Walenstadt and Weesen uninhabitable; increasing swamping of the whole Linth Valley; ship thoroughfare became impossible on the silted rivers, which braided due

Illustration 39:
Hans Conrad Escher of Linth (1767-1823)

to the irregular flow; the air was contaminated due to the swamps and epidemic illnesses increasingly spread. The object of the Linth enterprise is to prevent the growing power of this disaster and incidentally also to restore to some extent that which has already been spoiled.

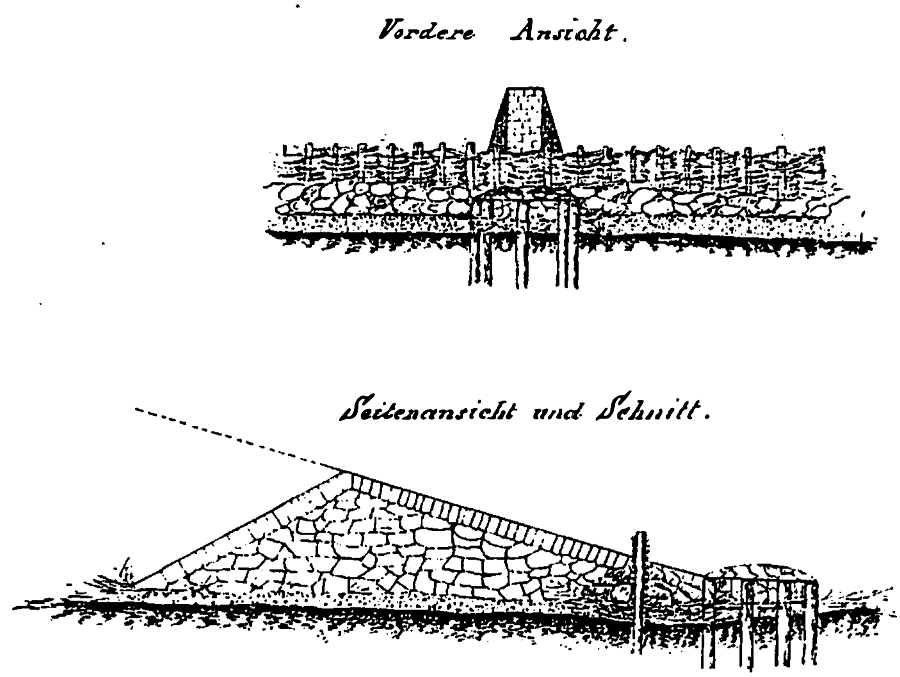


Illustration 40: *Bank protection: "Bank construction" from the hand-written report about the confederate inspection of the Rhone work from Blotnizki, 1867.*

"In order to put the first cause of the evil aside (the gravel of the Glarner-Linth) it is sufficient to lead the Glarner-Linth along the foot of the Walen mountain into Lake Walen itself. This was the plan which the deceased Captain Lanz from Bern had already proposed in 1783 and which was established following more rigorous investigations and a comprehensive assessment of the whole situation. In order to solve the second cause of the swamping, the raising of the Linth bed due to the deposited gravel, a new canal from Lake Walen to Lake

Zurich is necessary. At the point of greatest cut, at Ziegelbrücke, this has to be a full 16 feet deeper, and must continue with a descent as even and as steep as possible. It also must flow away in as straight a direction as possible. The flow of this canal and its direction are determined by fixed points; the Biberli head, Windecken and the corners of the upper and lower Buchberg, and partly also by the Ziegel bridge, which in many respects has been especially important for uninterrupted communication and ease of work. Because of the renowned accuracy of the survey carried out by Mr Fehr in Zurich, the infallibility of this solution was evident to every expert. It was without doubt that a river having a fall of 56 feet over an almost straight run of nearly 50,000 feet will flow away with sufficient speed to abolish any further tendency to swamping. This survey made it clear that the Linth, which had in the upper half of its course a slope three times steeper than that in the lower half, would produce increased swamping in the lower part of the valley, through which it flowed slowly, in long meandering curves.

"The first and most essential part of the whole Linth operation was to direct the Glarner-Linth into the depths of Lake Walen through the so-called Mollis canal. This work posed difficulties which were overcome more so by the genius of hydro-technicians than by the customary methods of the art. The uneven slope of the terrain which ran almost horizontal from the northern corner of Walen mountain into the lake necessitated an ascending elevation of the bed and a relative raising of the stopbanks. By tiresome shoving along of earth from the upper part of the canal, whose length from Lake Walen to the Näfels bridge is 13,000 feet, it was possible to produce a uniform gradient over a fall of 42 feet, or 3 feet 2 inches per 1000 feet. Considerable as this descent was, it was still surpassed by the descent of the Linth above Mollis, a situation which resulted in new difficulties. It was feared that the river, upon losing some of its velocity, would not be able to wash into the lake all the gravel which it had transported at a higher speed, but rather deposit part of it in the new canal. In order to prevent this, the velocity of the river needed to be increased to make for that lost by reducing its slope. This could be done by narrowing its bed. Such narrowing was also necessary because the Linth, like all mountain rivers carried only a small amount of water for most of the year and required a spacious bed

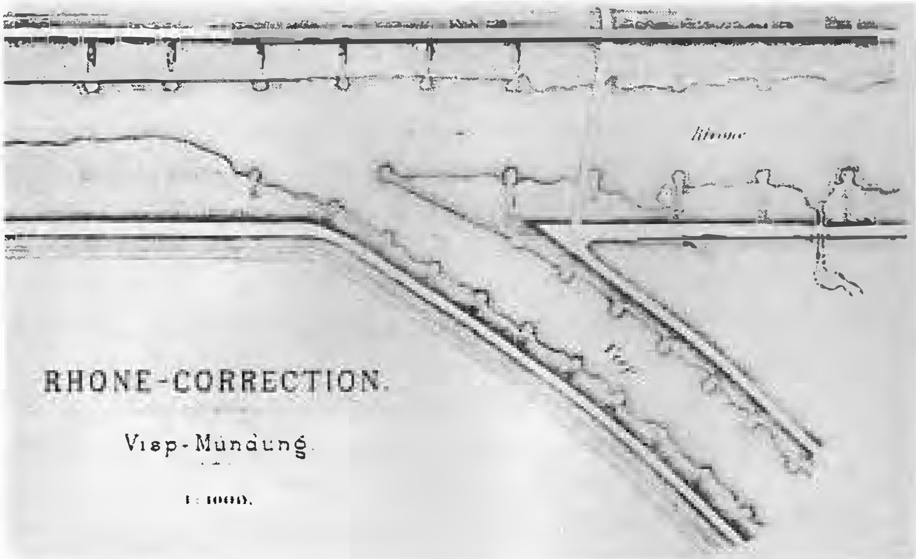


Illustration 41: *Training of the Rhone, mouth of the Visp, according to Salis, 1883.*

only for sudden floods. This is disadvantageous in the case of low water-level because it reduces the speed of the water flow. As a result, the water deposits the sand it is carrying, thereby raising the bed and forming sand and stone bars which give the stream disadvantageous bends and force the water towards the banks, thus presenting a danger. By repeated and careful measurements with instruments, which determine the movement of the water in a given time, the quantity of water which the Linth carried in one second at the highest water level of the year 1807, was determined at 4,750 cubic feet, and at normal water level 2,140 cubic feet. According to these results the new canal, whose embankments slope down at an angle of 45 degrees was given a depth of 8 feet and a breadth of 56 feet at the bottom and of 72 feet at the upper edge, so that it was able to carry the normal high water without being too large for the low water level. However, in order to fully protect the land from extremely high levels as for example those of the '60's of the previous century, 8 foot high stop banks were erected at a distance of 25 feet from both sides of the canal, which can hold 3 to 4 times larger amounts of water than the biggest normal high water level. Finally, in order to anticipate the most improbable, the right stopbank, *which runs along the foot of the Walen mountain was constructed one foot lower so that, in the most dangerous case, the water could run over to this side without causing damage, thus leaving the left side, which protects the whole of the Linth Valley, free from all on-rush of water.*

"To keep a rapid flowing river laden with gravel in such a narrow bed requires bank reinforcements which can resist any extreme impact. The banks, with a slope of 45 degrees, are therefore protected with strong stone pavings which have been made especially strong at the bend in the area of the Katzenbach, where the canal runs around the north corner of the Walen mountain in a curve of 1,175 feet radius. Likewise the stopbanks are covered with grass and are strong enough to hold the highest water-level. The lower part of the canal, which is to lead through the areas covered in water up to the depth of Lake Walen will only, after years, gradually be completed when the Linth will have sufficiently raised and filled out these areas with its gravel. Finally an extension of 3,500 feet is necessary above the Näfels bridge up to the Näfels-Allmend ...

"The Mollis canal achieved half of the greatest proposed aims and the accelerated continuing effect of those pernicious causes was put to an end. There still remains the saving of Walenstadt and Weesen, and the gradual drying out of the contaminated swamps. The conditions under which these purposes are to be achieved are: reduction of the water level of Lake Walen by 6 feet and as straight and uniform as possible drainage of this into Lake Zurich. The cause of the gradual rise of Lake Walen, the raising of the Linth bed at its union with the Maag upstream of the Ziegel bridge, had to be removed, and the river bed there had to be laid a full 16 feet deeper. For the solution to this extremely difficult task, the devices of customary river engineering were not sufficient because during the excavation of the so-called Ziegelbrücke canal water seeped through horizontally within a few hours due to the closeness of the Linth and to the many small waterways. Only by isolating themselves in single square pits whose walls were left standing, was it possible for the workers to excavate to 5 to 6 feet below the existing water level.

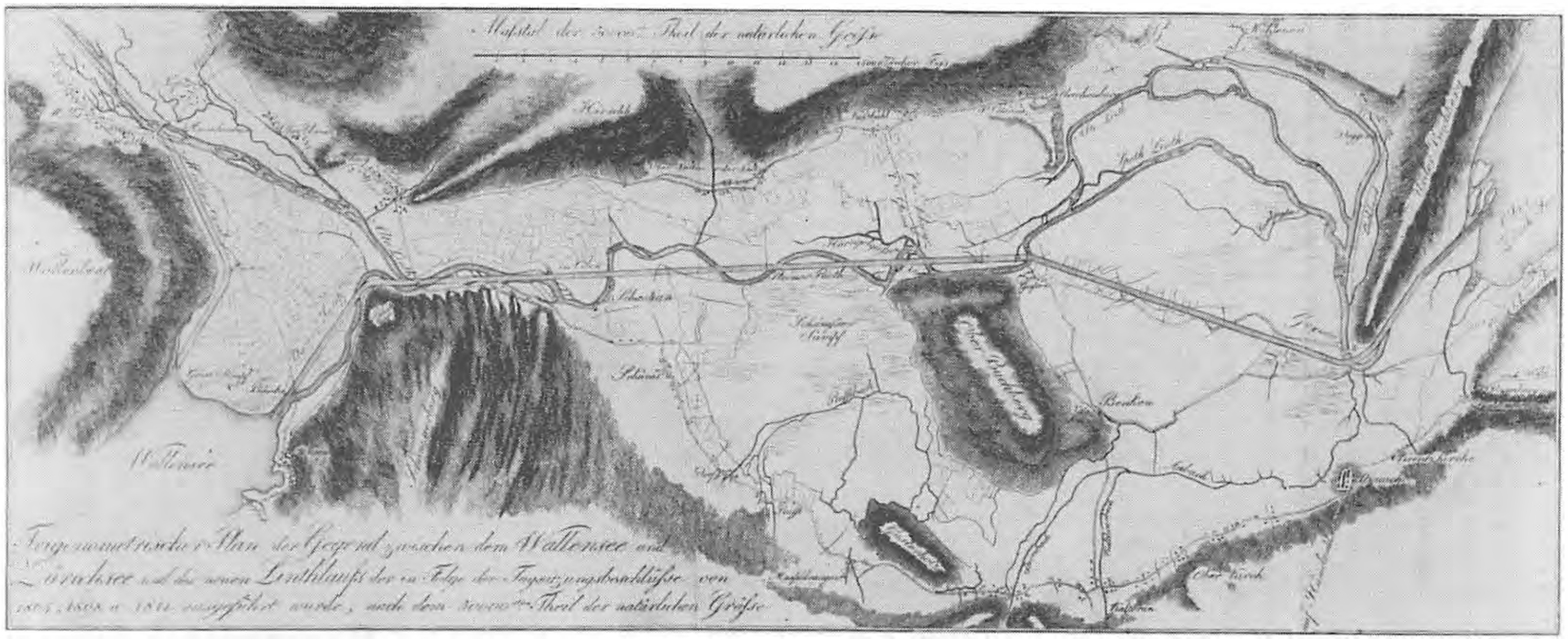


Illustration 42: *Training of the Linth river. "Trigonometry plan of the area between Lake Walen and Lake Zurich and of the new Linth route which was executed due to the confederate diet resolution of 1804, 1808, and 1811" according to the "official notice papers concerning the Linth enterprise", 1815-1824.*

"The final, difficult goal was reached only with the help of the newer hydro-technical experience and artifices which have been employed below the Ziegel bridge, where the direction of the new canal follows, for approximately 3500 feet, the old river-bed which is divided by many streams and islands. By confining the water in the new canal which was excavated to a width of only 58 feet instead of 90, the river could be forced to erode the bottom of its bed, which consisted of sand, gravel and, at upper Windecke only, clay. Also, it would have been an extremely expensive and meagre effort to cut the new canal through the islands, sand banks and irregular projections of the old Linth bed, and to fill in the old cavities. All this was carried out by a means belonging mainly to the newer hydraulic engineering techniques and which is actually the key to the secret of leading a stream at will: through so-called fashine works.

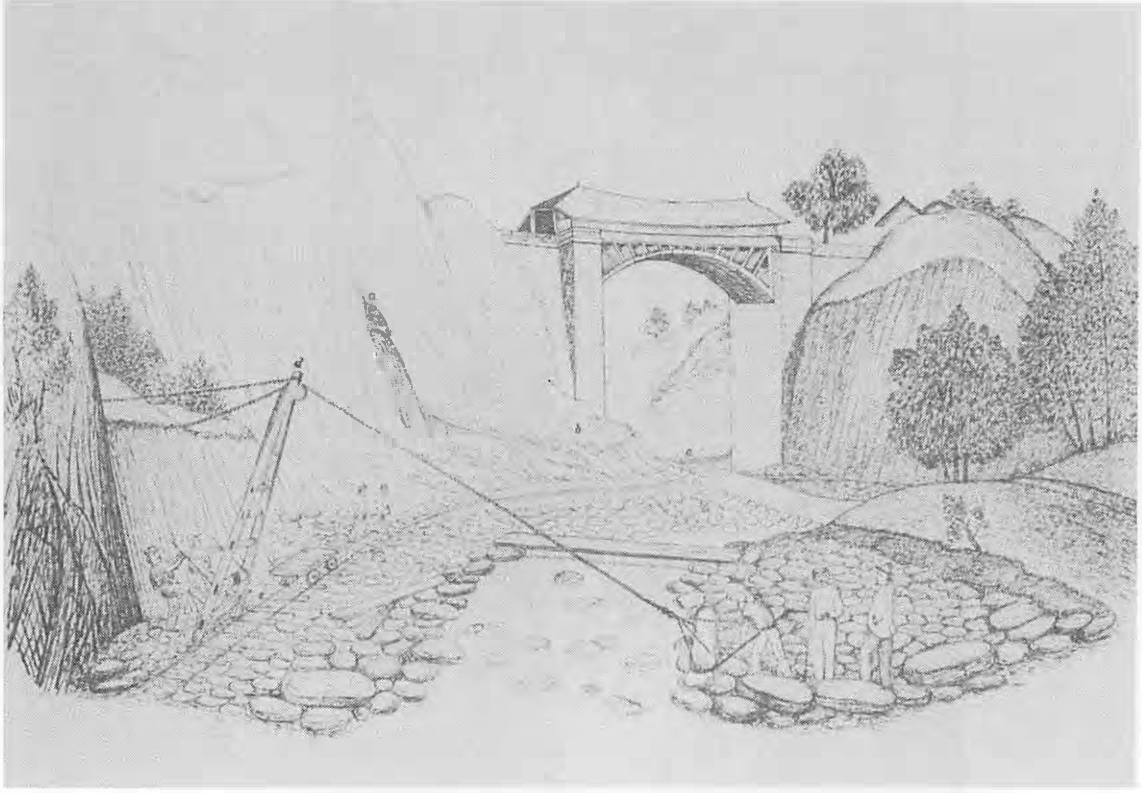


Illustration 43: *Rip-rap: Installation of a crane called "Goat" from the handwritten report about the "confederate inspection of work on the Rhone" from Blotnizki, 1867.*

"From a firm position on the bank, a type of wall made from many layers of perennial plants connected by wicker work is extended into the river in an upstream direction. This wall detains the flow somewhat and can also alter its direction. Such a work is called a fashine spur. If two such spurs are placed opposite each other on both banks, the velocity of the river is increased due to the narrowing. If its condition allows it, this, together with the increased pressure of the water, erodes the bed and thus the river washes out the ground of its own bed. Through a properly ordered row of several such spurs not only is the stream deepened over a considerable length, but also the gravel swept away is deposited in the quiet water between the spurs along the banks. Thus, new connecting banks are formed out of gravel which otherwise would have been carried to the lower reaches of the river. Because the river end of each spur descends in a curved line below the water level, as the river bed deepens, the ground beneath the spur is washed away. This leads to a decrease in the length and effectiveness of the spur until finally it withdraws itself to the appointed natural bank. Due to this device, which has hardly been used anywhere else to such an extent, and which may only be installed and used by experts and under police supervision, all desired goals were perfectly attained in the high waters of spring in 1808 and 1809 by means of 15 strong fashine works. The islands and sandbanks, now washed away, could be seen in extended deposits along the new bank line between the fashine works. The river bed had deepened itself to such an extent that the increased drainage of the water had an effect upstream, whereby the Ziegelbrücke canal was washed out 10 feet deeper. At present the old Linth bed lies five feet higher than the surface of the water running in the new canal. Several old wooden Linth dams, put in long ago, could now be seen and could be ripped out, although not without effort. A 10 foot deep rammed-in bay of the Ziegel bridge was washed free, so that the bridge itself had to be altered. Without doubt the deepening would have been much more considerable if a ridge of rock across the river at upper Windecke, which now came to light, had not hindered the increasing velocity of the water.

"Nevertheless, the lowering of the river which was achieved was so significant that the canal sections above the Ziegel bridge, the so-called Biberli canal and the Weesen canal, which previously had been covered by four to six feet of water even at the lowest water level, could now be worked on. Not without astonishment could one now walk around whole stretches of country upon which no man had stood for 40 years. The inhabitants of Weesen and Walenstadt now discovered the blessed results of the enterprise in a way which could also convince the most disbelieving, because in spite of the swell of all the remaining waterways in March of this year, their flats remained free for the first time from all flooding of the lake. In Walenstadt one already had to think about deepening the port which the lower water level threatened to make redundant.

"But however admirable the effect of the increased flow may have been, it was not able to wash away the partition walls because they consisted of firm clay with tenacious roots growing through. These were used at the excavation of the canal as protection walls against the intruding water. A new expedient, that was itself unknown to the foreign hydro-technicians, relieved this difficulty. From an anchored ship, the downstream side of the wall to be washed away was churned up with an iron-clad paddle, approximately 70 pounds in weight and twelve feet long, across which a three foot long plank was fixed. The stream then swept away the separated roots and the loosened mud. These drill-paddles also served for the removal of old stone dams and "sinking" whereby pieces of rock larger than 50 cubic feet were worked loose ...

"Because the rock ridge, which appeared in the deepened Ziegelbrücke canal, hindered the quick passage of the water and consequently further deepening, it was essential to overcome this unwelcome hindrance. A detour around the rock, which lies in the middle of a canal approximately 16,000 feet long, was not advisable. It was also likely that due to the position of the strata on the mountains on both sides of the Linth Valley any other canal direction would encounter the continuation of this rock. Nothing else could be done but to blast the ridge of rock in places.

'This was a very difficult task because of the hardness and uneven composition of the stone, which consisted of a very coarse-grained conglomerate, and because of the depth of twelve feet to where the river bed needed to be cleared.

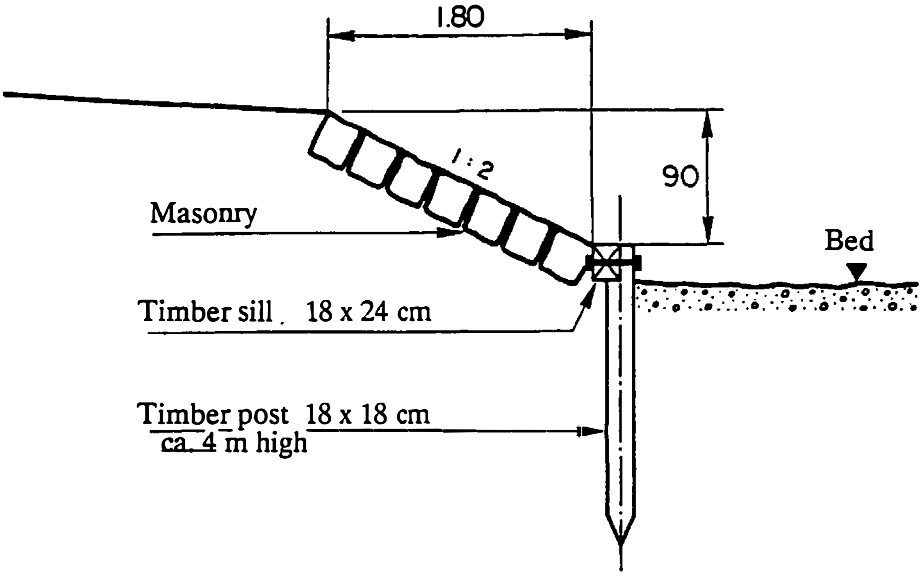


Illustration 44: *Bank protection for the correction of the Birs River 1872 (according to Golder 1984).*

"Also this part of the Linth construction was enriched with considerable improvements by the knowledgeable leader of the whole work (referring to Escher). In place of the hitherto expensive method used to blast under water he invented an easier and more effective procedure which, in short, consists of the following: a wooden pipe protruding over the water surface was driven into a hole drilled in the stone for blasting. Through a tube, which was inserted in the drilled hole, the water was sucked out; when necessary small fissures and joints which allowed water to pass through were sealed with clay. Then the gun-powder, in which a hollowed reed containing the igniter was set, was poured in. The remaining spaces in the drilled hole and the pipe were filled with loose dry sand. This extremely simple procedure achieved the same effect as that attempted at other places - the blasting of the rocks of the

Danube rapids, for example - using very expensive apparatus including metal cartridges and iron wedges, all of which had less certain success.

"The technique of filling with loose sand instead of firm packing with stone sand had been discovered five years earlier by Jessop in England. It was put into practise here for the first time by blasting under water, and was also immediately employed to advantage in blasting at the Walen mountain which supplied the stones for the Mollis canal. Its effect is often better than the usual method which, because of the packing of the filling, is time consuming and very dangerous.

"Almost at the same time as the works on the upper canal, work was being undertaken with zeal on the lower sections. Already by March of 1809 the so-called Niederurnen canal was opened to the river for a length of 2,300 feet. The erosion immediately following made it possible to demolish an old Linth dam lying across the river. Another dam of this type, which had been freed from sand during the spring water of the previous year, gave the river an extremely disadvantageous direction to the left side of the bank. The bank had been undermined to a depth of 24 feet and threatened to cause the collapse of a dam built one and a half years earlier for the protection of the large area between Niederurnen and Bilten. Fashine dams, built during high water under the most difficult circumstances, succeeded in holding this dam and protected the land from a devastating flood. In the lower part of the Niederurnen canal, considerable sand banks appeared as a natural result of the exit of the canal through the old raised Linth bed and the correspondingly retarded flow. These were washed away by this year's floods with the help of a few fashine spurs.

"In the following section, 4,200 feet long, bearing the name Schänis canal, the Linth began flowing from 22 December of the previous year. Unexpected problems were caused by the sinking of the dams which were founded mainly on loose peat ground and already had been raised four times in a row, and the removal of the old Linth dam which led a part of the Linth into the still incomplete canal (Spring 1809).

"Because it was not possible to dig the land deeply, due to the low terrain, it was necessary to cover the lower banks of the river with small fashine spur dykes in order to raise them gradually by deposition of the Linth mire. Despite the lack of usable earth, big pits dug near the banks in order to complete the stopbanks will be filled within a few years with deposited mud from the high Linth waters. The exit of this canal, which flows over sandy ground, deepened by a full ten feet soon after its opening. Below the Schänis canal, work on two canals, the Bilten and Steinerried canals, was still going on.

"The Bilten has been excavated in a clean cut manner due to the nature of its bed which consists of firm clay. The Steinerried on the other hand, which touches the Schänis swamp, is secured by fashine spur dykes because of the lower depth to which it can be excavated. This is also necessary for the channel in Auschachen which runs entirely through the swamp. The part of the canal in Hängelgiessen, lying upstream of it where it is less swampy, will have been excavated before the high waters of this year...

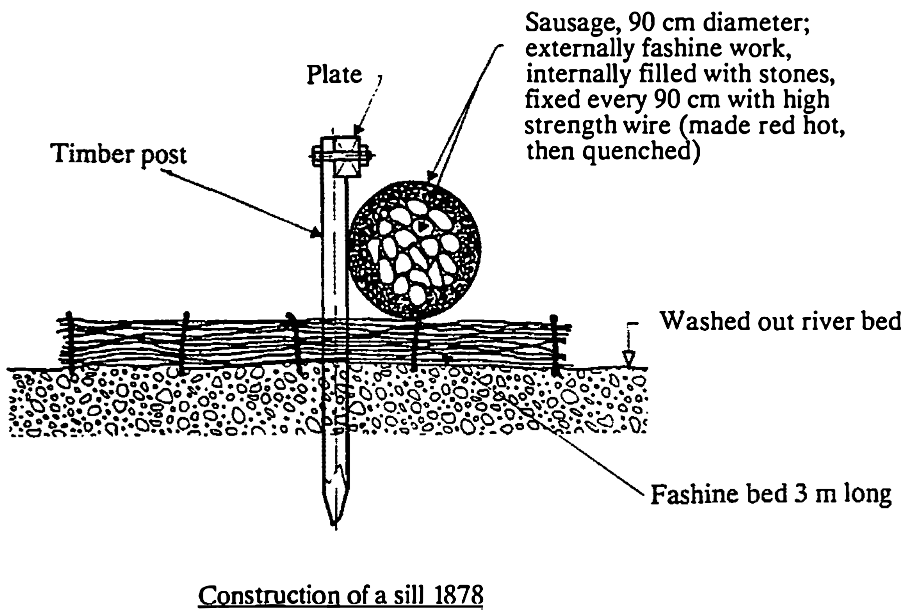


Illustration 45: *Sill for the correction of the river Birs 1878 (according to Golder 1984)*

> *"This is the volume of the works of the Linth enterprise executed so far. The Mollis Canal is finished up to one quarter of its length and requires only the completion of the stone dam. Almost half of the length of the 50,000 foot canal between Lake Walen and Lake Zurich has been excavated and the Linth already flows through approximately 15,000 feet. All of these canals are enclosed by high and strong stopbanks clad with grass, and are capable of protecting the land from the highest waters of the river. The stopbank on the right hand side of the river is strengthened and has been covered with gravel in order to serve as a path for pulling ships travelling upstream to Walenstadt; an advantage which must be recognised by everyone who had seen the terrible old path that could not be used without danger to people and horses. Wide drainage ditches are situated behind the stopbanks. At several places these serve to drain the mountain streams and prevent the livestock from getting near the stopbanks which would damage these precious works ...".*

So much from the commission report to the confederate diet of 1810.

The detour of the Linth from Mollis to Lake Walen commenced on 8 May 1811. The Maag-Linth Canal from Weesen to Grinau was opened on 17 April 1816. That completed the essential parts of the Linth scheme, and soon it showed its first positive effects. However, high waters in 1817 caused flooding again and necessitated new works. Nevertheless these floods were of use in so far as they washed out and extended the new river beds. It is remarkable that in 1827 the share holding enterprise was finished. The shares were withheld until 1845, that is, reimbursed, minus the presented amount of about 10% of the total cost (Meier 1985). Escher did not live to see this conclusion; he died on 9 March 1823 at the age of 56, commemorated as highly honoured saviour of a landscape and its thankful population. The diet which had honoured Escher several times during his life decided in June 1823 to give to him and his male descendants the honourable appellation "von der Linth", and to re-name the Linth canal from Mollis to Lake Walen, which is actually the heart of the Linth works, the Escher canal. Further, it was decided to erect a monument at the Ziegel bridge at Biberlikopf. This turned out simpler than planned but still impressive enough (Becker 1910).

It consists of a commemoration plate fixed on a rock of conglomerate with the following inscription:

Jo. Conrado Eschero Lindemagico paludibis siccatis.
de patria bene merito ob cives servatos honoris et virtutis causa populus helveticus ex conventus decreto posuit

MD CCC XXXII

To the benefactor of this area
Johann Conrad Escher "Von der Linth",
born 24 August 1767, died 9 March 1823,
The confederate diet,
Thank him, the inhabitants owe him health,
The river its orderly bed,
His mind raised nature and fatherland
Confederates!

Let him be your example

As already mentioned, the major parts of the Linth scheme were finished only in 1816 and, even after the death of Escher, needed to be adapted and refined. The Escher canal had to be extended through the delta it deposited into Lake Walen as well as the Linth Canal from Grinau down into Lake Zurich. *"It was however, especially the back-waters"*, as Becker (1910) writes,

"that had to be regulated in order to allow for drainage into the main canal which they could not drain into because of the high stopbanks. For management and administration of the whole Linth enterprise a permanent committee, the so-called Linth Police Committee was founded. This consisted of one representative of the federation and of each of the cantons Schwyz, Glarus, St Gallen and Zurich and one Linth engineer. The Federal colonel La Nicca, who was a highly honoured hydraulic and road engineer throughout the whole of Switzerland, worked from 1827 to 1863 as the first Linth engineer. In 1844 Gottlieb Heinrich Legler from Glarus was assigned to La Nicca as assistant. He became his successor in 1863 and fulfilled the role with loyal dedication until his death in 1895".

To Legler we owe the excellent descriptions of the Linth work as well as many other river training projects.

4. The first water trainings of the Jura (1868 - 1891)

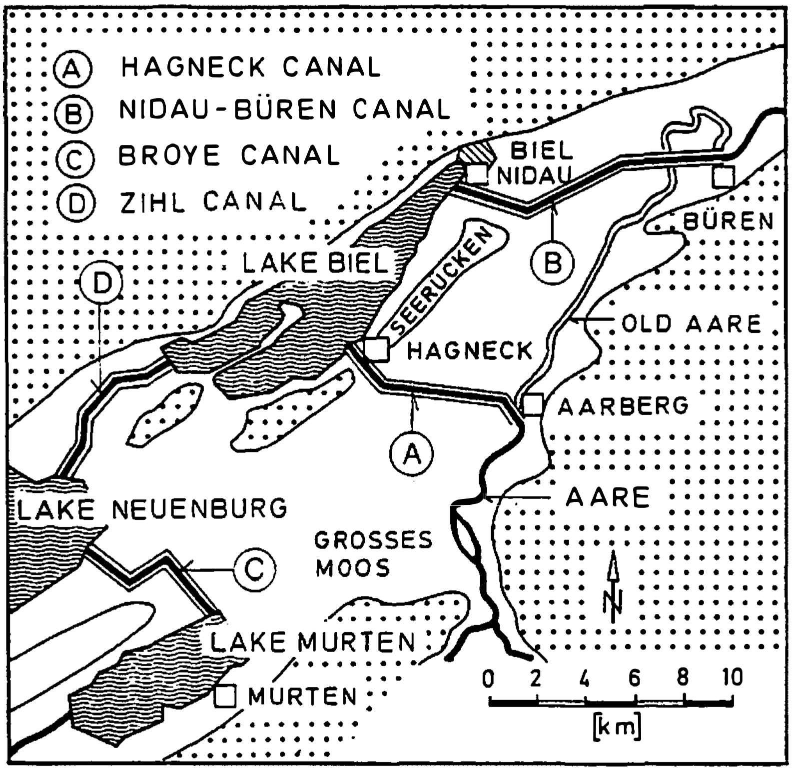


Illustration 46: *The first water trainings of the Jura 1868 - 1891*

Upon leaving the hilly zone near Aarberg the original run of the Aare - known today as the old Aare - skirted the large plain between Lakes Murten and Neuenberg, the so-called Great Moor. It then crossed through the wide expanses in many meanders to Solothurn via Büren. The slight slope of this stretch, almost 30 km long, led to gravel deposits and constriction in the river bed. This hindered runoff of high waters and resulted in repetitive flooding. According to old chronicles, it appears that the frequency of these adverse events increased in the mid sixteenth century. The settlements in the bordering areas suffered increasingly from water damage, the crops and harvests in the cultivated areas were repeatedly destroyed, the ground gradually became swamp. Correspondingly the cries for help from the population grew louder, until from 1704 onwards the government in Bern - here the author follows largely the reports by Stambach (1970) and Ehrsam (1974) - commissioned a dozen experts one after the other for the formulation of training projects.

One of the experts was Johann Gottfried Tulla from the Grand Duchy of Baden, who, in his expert opinion, came to the conclusion that gravel was the cause of the evil. In clear appreciation of the hydraulic situation he advised river improvements in the area where the Aare unites with the Zihl which flowed out from Lake Biel. Both waters should be re-routed and straightened to the extent that the confluence would be shifted from Meienried to Altreu, about 10 km downstream. Tulla also contemplated continuing training the Aare up to below Solothurn to the mouth of the Emme, including removal of the Emme delta which hindered the flow of the Aare. He likewise contemplated training the Broy stretch leading from Murten to Lake Neuenburg and the Zihl stretch leading from Lake Neuenburg to Biel. Even more interesting is Tulla's idea which was a basic alternative, to lead the Aare either into Lake Neuenburg or Lake Biel.

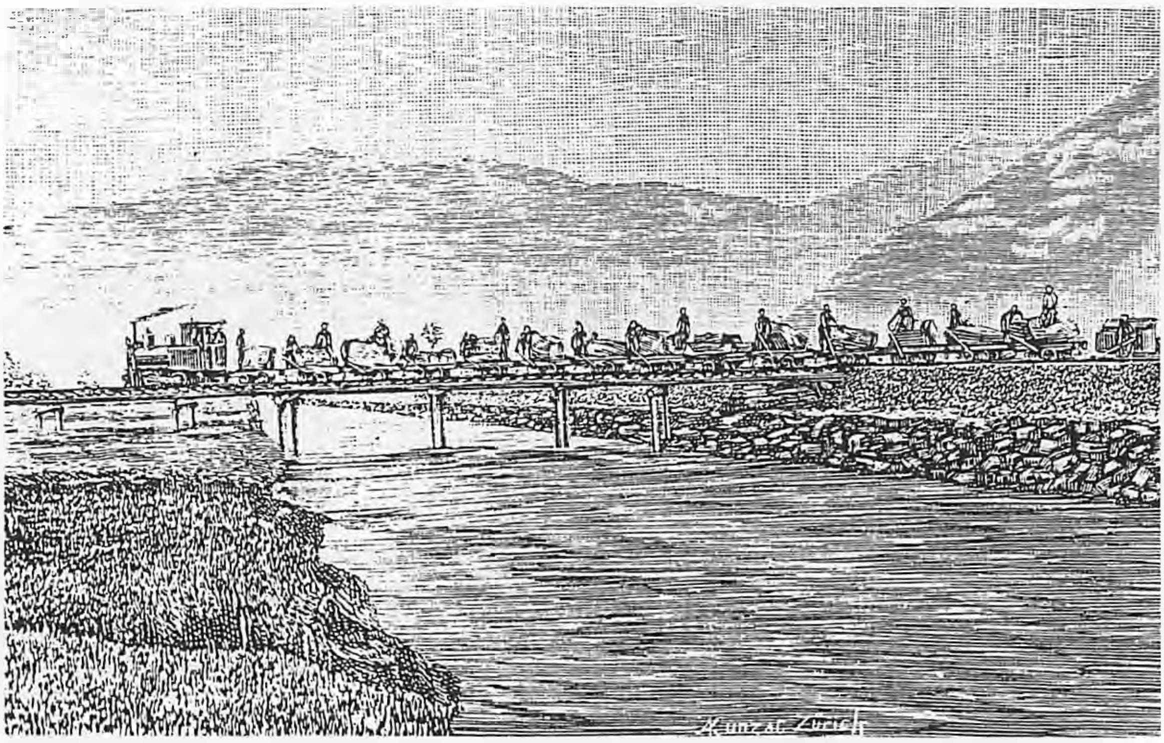


Illustration 47: *Rip-rap. Sketch based on Illustration 50. A historic view of the training of the Tessin around 1890*

However, these projects existed only on paper until further flooding proved their urgency. The experiences perceived by the population from a flood catastrophe have been described in moving terms by Dr Johann Rudolf Schneider who grew up in Meienried:

"... truly a sad, terrible sight to see so many thousand hectares of fertile land with all its fruit buried under water! The misfortune is immeasurable. Lost, completely lost are the fruits of the indefatigable diligence of this industrious population. The three lakes of Murten, Neuenburg and Biel seem to constitute only one large water basin. In the middle of this, Landeron and Nidau stand like an island of houses. A traveller told me today that the upper Broye and the Orbe have also overflowed, the Moors from Chablais, Orben and Iferten stand likewise under water. The sight yesterday must have been frightful when the plains from Jensburg to Solothurn were also flooded by the Aare, which as you can now see, has already withdrawn. The Aare rose unexpectedly quickly during the night before last and carried away with it, over large stretches of land, sills, weirs and dams which had been constructed with such toil; the disaster was especially dramatic from Kappelen down to Meienried. When I woke in the morning the water was almost at my door; with other people the water entered into the houses, even into the sleeping quarters of those still asleep. The villages of Schwadernau, Scheuren, Meienried, Reiben, Staad and Altreu stood completely in water. At Meienried the Aare climbed 21 feet 8 inches above its lowest level. Most of our meadows were mowed, however, because of the persistent rain nothing could be collected and so the floods carried away the hay. Also a father and a child died in the floods. Our cornfields were covered with mire, sand and gravel in only a few days. Especially if, as it appears, we are to have hot weather, we will no longer have one healthy corn ear. The potatoes have been completely lost, the villages have been filled with a conglomeration of filth and the houses have become the refuge place for all vermin ..."

Epidemics followed each respective flooding, and the number of deaths in the low lands were enormous.

The catastrophic floods in the years 1831 and 1832 lead to the founding of a committee by a group of men under the leadership of Schneider. It investigated the possibilities of controlling the Aare and summoned action through newspaper articles, leaflets and brochures as well as meetings with the inhabitants. The group achieved success insofar as it was transformed into a preparation society by a decree from the cantons Bern, Freiburg, Waadt and Neuenburg. This entrusted, in 1840, the exposition of a solution to the government senior engineer and first Linth engineer Richard La Nicca.

Illustration 48:
Richard la Nicca
(1794 - 1883)

In March 1842 La Nicca presented his first project. It consisted of the following suggestions for river training:

- diversion of the Aare from Aarberg into Lake Biel
- discharge of the united Aare and Zihl waters from Lake Biel to Solothurn
- training of the Broy stretch which led from Murten into Lake Neuenburg, as well as the Zihl stretch which leads from Lake Neuenburg to Lake Biel
- drainage of the "Great Moors" and the bordering areas.

The suggestion to divert the Aare from Aarberg via the Walperswil-Taeuffelen-Moor and through a cutting of the hills (at the lake) at Hagneck into lake Biel, was so radical that initially it brought no consent from many circles. Even experienced technicians spoke against it. Many did not want to believe that it would be possible to lower lake Biel by leading more water into it via the Aare. In convincing those who were sceptical, it had to be realised that the initial negative experiences with the diversion of the Kander certainly had their aftermath. The related, Aare training from Thun to Uttigen was not completed until 1873. The only positive example was the largely finished training of the Linth. It therefore required intensive instructional work by the preparation society, to make it clear to the population that at times of high water a much smaller amount of water than earlier was to be led from lake Biel, and that at the same time the whole mass of gravel of the Aare could be immersed in this lake. Twenty-six years elapsed until the first sod for the river training was turned. The political conditions of the time were largely to blame - for example, the turmoil of a civil war - as well as the lack of any legal base. The fact that the training extended over five cantons, among which the negotiations were often very slow, also added considerably to the delay. In addition difficulties with finance arose, continual doubt emerged, avaricious objections, obstinacy and jealousy. The battle for La Nicca's project was indeed very intensive.

It was only the federal constitution of 1848 that brought legal support for the implementation of the project. In Article 21 it stipulates: *"The federation has the right to establish public works at the cost of the confederates as well as to support the establishment of this, and for this purpose to make valid the right of the expropriation"*. But now new opposing projects continually emerged, which were why the federal government needed to order several technical expert analyses. However, in December 1863 the federal meeting declared that the Jura water training was to be carried out according to the plan of La Nicca under this article 21, and granted a federal contribution of almost 5 million Swiss franks.

In the Spring of 1865 flooding of huge proportions occurred again. The water inundated practically every moor and made it appear as if lakes Murten, Neuenburg and Biel were just one lake. As a consequence of this event all five of the cantons decided, in July 1867, for the execution of the training works. The Federation rounded up its contribution under the condition that the training would be carried out according to the project of La Nicca-Bridel, modified by federal advice experts. The following work also had to be included:

- diversion of the Aare from Aarberg into Lake Biel via the Hagneck canal

- drainage of the water from Aare and Zihl which collected in Lake Biel through the Nidau-Büren canal to Büren

- training of the upper Zihl between the lakes Neuenburg and Biel

- training of the lower Broye between lakes Murten and Neuenburg

- execution of the training works between Büren and the mouth of the Emme, as far as it proved to be necessary.

The draining of the Great Moor and the bordering areas, which La Nicca had designed in his first project, fell through due to financial reasons. The Nidau-Büren canal was to be constructed in seven years and the Hagneck canal in ten. The trainings on the Aare between Büren and the mouth of the Emme, as well as at the lower Broye and the upper Zihl were set a time limit of three years, calculated up to the final placing of the Nidau-Büren canal and the lowering of the mean water-level in Lake Biel.

These conditions imposed by the federation were accepted by the cantons and the training began its construction stage. Each canton had to create its own organisation for the river training because mutual construction management could not be agreed upon. The diversion of the Aare from Aarberg into Lake Biel via the Hagneck canal and the drainage of the water from the Aare and Zihl uniting in lake Biel via the Nidau-Büren canal to Büren lay in the hands of the Bern canton. Engineer Gustav Bridel from Biel was chosen as chief engineer, and Karl von Graffenried from Bern was his successor; the government supervision was carried out by the so-called drainage management. The engineers Fraisse from Lausanne and La Nicca were the confederate inspectors.

Subsequently, the construction programmes were worked out, the construction plans made public, the acquirement of land organised and the machinery procured. The latter consisted of two steam excavators, two steam cranes, 24 transport ships, 122 tipping carts, 60 trolley cars, two small locomotives and four kilometres of railway tracks and the necessary railway sleepers. As a site for the technical management building Nidau made available the old town hall and established a telegraph office.

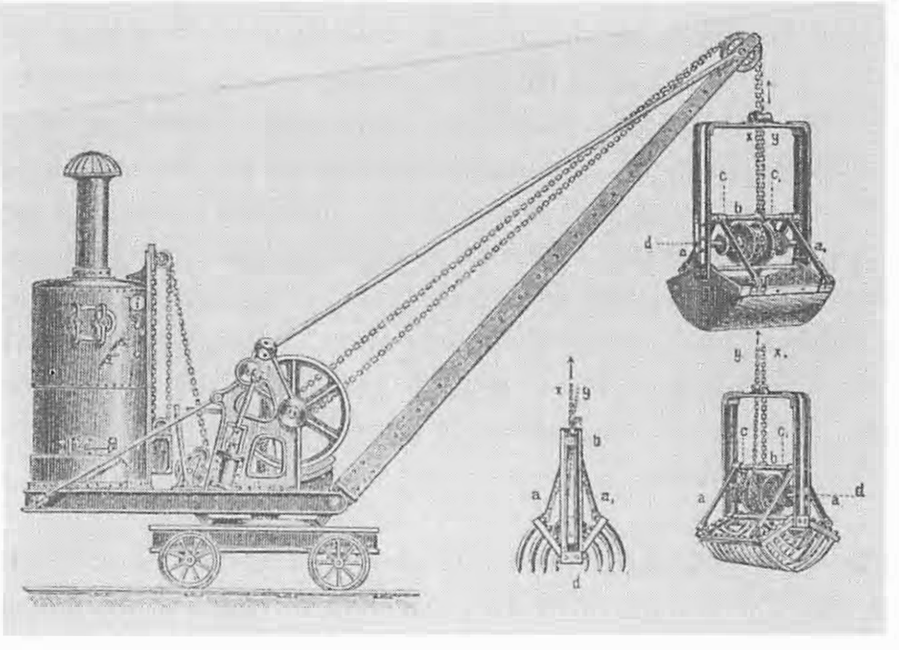


Illustration 49: *Steam excavator on tracks from "Water Engineering" by Franzius, 1890*

Likewise in Nidau a large repair workshop was established in which several iron bridges were later constructed. Furthermore, the enterprise secured the purchase of about 300,000 cubic metres of limestone for bank protection as well as the fuel necessary for the construction works. The excavators and steam cranes as well as the repair workshop required around 2,200 kg of coal monthly. After the outbreak of the German-Franco war and especially after the occupation of the Saarland by German troops, it became impossible to obtain, the coal regularly. As a result the work had to be stopped in February and April 1871 for a long period. At the same the price of coal climbed from Fr 2.90 to Fr 5.00 per 100 kg.

Before the Aare was diverted into Lake Biel, the discharge from Lake Biel that is, the Nidau-Büren canal, had to be almost completed in order to avoid the negative experiences of the Kander diversion previously mentioned. In August 1868 the first sod was turned. Once the canal at Meienried was finished, the resulting increase in discharge from Lake Biel occurred so quickly that the water level there almost sank lower than La Nicca had predicted. This caused certain problems, which will be mentioned later.

For the diversion of the Aare a provisional leading canal from Aarberg to Hagneck was dug five to ten metres wide. It was left to the waters of the Aare to carve out a wider channel. However in order to prevent this water flowing too early into the leading canal, the canal was barricaded at Aarberg. Correspondingly the Aare temporarily retained its old bed to Meienried at Büren. The further progress of work then permitted the removal of the barrier at Aarberg on the 17 August 1978, that is, the partial diversion of the Aare into the leading canal. The guests invited on that day, however, had to do without the show because the Aare anticipated the event. With a flood on 16 August it flowed over the barricade and continued flowing partially in the direction of Lake Biel. Among the defrauded but actually very content guests was the doctor Rudolf Schneider.

At first the approximately 100 cubic metres per second of water flowing from the Aare into the leading canal were not able to widen it significantly. The desired process of erosion was considerably slower than hoped. In 1882 only about 40% of the Aare waters flowed through the Hagneck canal into Lake Biel and it took until 1887 to fully complete the diversion, i.e. for the leading canal to be widened to the defined dimension. By then almost two million cubic metres of gravel and earth had been washed into Lake Biel. Unfortunately the erosion in the Hagneck canal developed even further so that in 1888 major works to secure the banks had to be carried out in the Hagneck cut. In 1891 the Hagneck canal as well as the Nidau-Büren canal were officially examined. Their total cost amounted to 14 million Swiss franks. This sum also included the labour cost for the newly constructed bridges.

As already mentioned, the construction of the Nidau-Büren canal caused a considerable lowering of Lake Biel. This process was only partially compensated by the inflowing Aare. The resulting extraordinarily low low-water level of Lake Biel was detrimental to the stability of its banks. A combination of this and other influences caused bank collapses and slides at several sites. The enterprise had to cover the damage. As a counter-measure a provisional weir was constructed in the Nidau-Büren canal above Brügg. The building of a sluice near Nidau was also considered at that time. The lowering of the water level in Lake Biels completely corresponded to expectations in removing the danger of flooding around the lake. Additionally, the lowering of the lake created a lot of beach area free of water which could be sold by the enterprise to interested customers, thus procuring urgently required income. For example, in 1873 the town of Biel acquired two hectares of beach land for Fr. 8,850-, which is a price of Fr. 0.41 per square metre. At the same time, in other counties, 58 hectares were auctioned at the price of Fr. 0.07 per square metre! Similar sales of beach land also took place elsewhere including the neighbouring cantons which were positively affected by the lowering of the lake.

Although the federal resolution of 15 July 1867 determined that the further training works were only to be allowed after the construction of the Nidau-Büren canal, already in October 1872 the Bern government invited the cantons Freiburg, Waadt and Neuenburg to train the upper Zihl. The reason was that Lake Biel had already been lowered sufficiently and as a consequence there was no more flooding in the upper Zihl area. The invited cantons came to an agreement on the communal construction and chose engineer Henri Ladame from Neuenburg and later engineer Borel as chief engineers. The site of the construction management took place in Murten then in Sugiez and later in Thielle. Technical experts of the federation were the same as those for the Bern training - the engineers La Nicca and Fraisse. Building equipment, was bought on the spot as it became available from the Bern canton. This was advantageous to both sides. The missing machinery was built at a factory in Sugiez.

The correction works consisted of excavations at the Broye and three large cuttings at Sugiez, Tour de Chene and La Monnaie. The dry excavation material was used for the filling up of the neighbouring low-lying areas. The wet excavation material, on the other hand, was loaded onto barges and dumped into the Lake. The stones necessary for canal bank protection and for the jetties in the lakes Murten and Neuenburg were taken from quarries on lake Neuenburg. By 1878 the main works had been completed. The bank protection proved to be too weak for the passing of ships and had to be supplemented. This took until 1883. With the new bridges from Sugiez and La Sauge the Broye canal cost around 1.7 million Swiss franks. It was officially accepted in 1886.

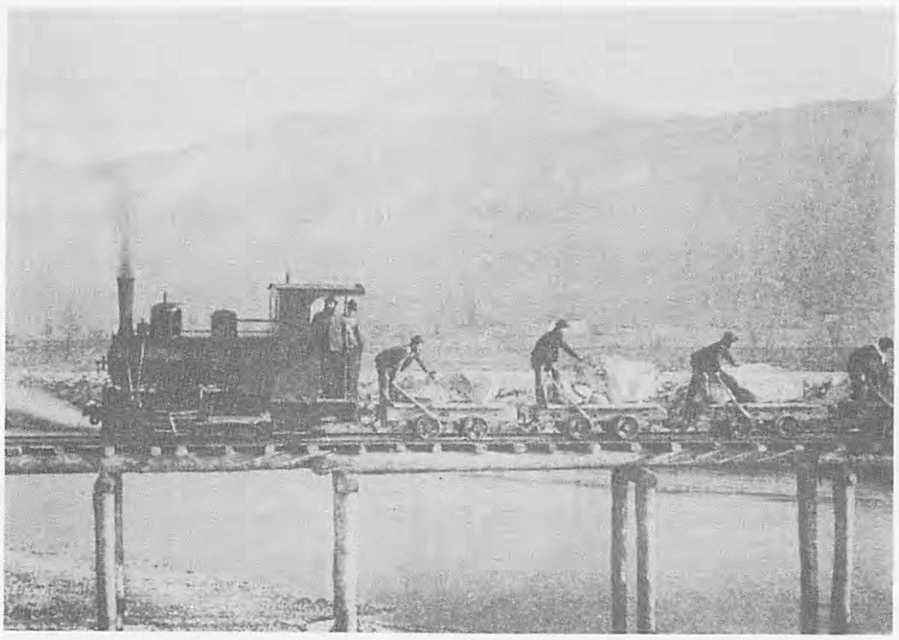


Illustration 50: *Rip-rap. Operation of the steam traction at the Tessin training according to Martinoli, 1896 (photo probably taken in 1889)*

The works at the Zihl canal consisted of excavations and cuttings at Cressier and Thielle. As with the Broye canal all excavation material was dumped in the lake. The stones for bank protection and the jetties did not only come from the already mentioned quarries at Lake Neuenburg but also from those at Lake Biel. After the main works had been completed in 1878 the bank protection here also proved to be unsatisfactory.

Furthermore the jetties in Lake Neuenburg were too short, thus requiring supplementary works. The iron bridge from Thielle was newly constructed, however the old wooden bridge of St Johannsen was left. The Zihl had formed the border between the cantons Neuenburg and Bern before the training. Afterwards some landmarks, for example the Thielle castle, came to be situated on the right bank of the Thielle instead of on the left, while at Cressier an area belonging to the Bern canton came to be situated on the left bank. The abandoned river arm was not filled. Altogether the Zihl canal cost around 2.7 million Swiss franks and was officially accepted in 1886.

The lowering of lakes Murten and Neuenburg, occurring as a result of the canal construction, did not result in bank collapses and slides. However the harbours and numerous wharfs were laid dry, as predicted. The enterprise was also responsible for the work necessary to adapt to this new situation.

Training works on the Aare stretch Büren-Attisholz, downstream of Solothurn, were not carried out. This gave occasion to certain disagreements and remonstrances against Solothurn canton which was responsible. These works were, however, not altogether necessary because the preceding training works diminished the flow of the Aare at Solothurn to such an extent that the available size of the Aare river bed was now sufficient. In 1891 the whole first Jura water-training was completed. The draining of the areas bordering the Jura waters, which were not part of the main Jura water training project, was left as the responsibility of the individual cantons. Naturally some after effects resulted: the continual erosion in the Hagneck canal has already been mentioned. The bank movements in the Hagneck cut did not stabilise for a long while and ultimately made new construction of the Hagneck bridge necessary. In order to obtain definitive conditions, between 1897 and 1900 the power station at Hagneck was built at the canal mouth into Lake Biel. It dammed the canal for a length of almost 4 km and thus broke its power to erode.

The provisional barrier dam above Brügg in the Nidau-Büren canal did not live up to expectations. It was revised and improved several times but could hardly withstand the unusually large flood of 1910. New construction modifications were also only provisional so that in 1936 to 1940 the Bern canton took measures to establish a modern sluice at Port. With that the regulation of Lake Biel, and connected Lakes Neuenburg and Murten, was guaranteed.

In general, the first Jura water training was very successful. The training meant, as Ehrsam (1974) writes:

> *"for the region, a freeing of century long flooding with its swamping and other disturbances, which left the population to vegetate in poverty because neither healthy agriculture nor industry could develop. Where the land had been scarcely accessible previously, after construction of the inland canal system and after systematic treatment of the ground and fertilization, there now stretched the most abundant vegetable cultivations. In place of reeds and inferior grass, valuable corn, potato, sugar-beet and vegetables of all varieties were planted. In the beautiful villages a healthy population developed. The thankful inhabitants erected a monument in 1908 in Nidau for the main instigators of the Jura water training, the doctor and politician Johann Rudolf Schneider and the ingenious federal engineer Richard La Nicca, at the place of their first work".*

The fact that 70 years after completion of the first Jura water-training project, a second proved necessary (accomplished in the years 1962 to 1973) does not speak against the far sightedness of these men. For in the training of rivers, no measures can be taken that will last forever; on the one hand the waters and the beds of these change. On the other hand the demands of the inhabitants concerned change also.

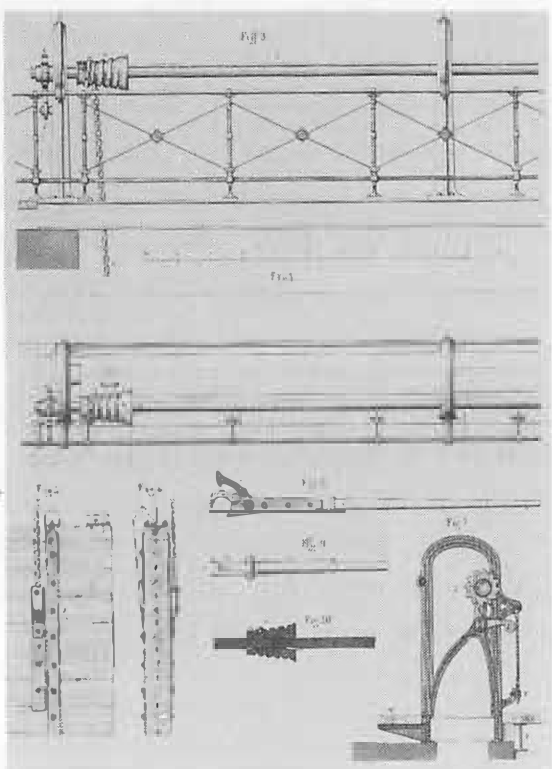
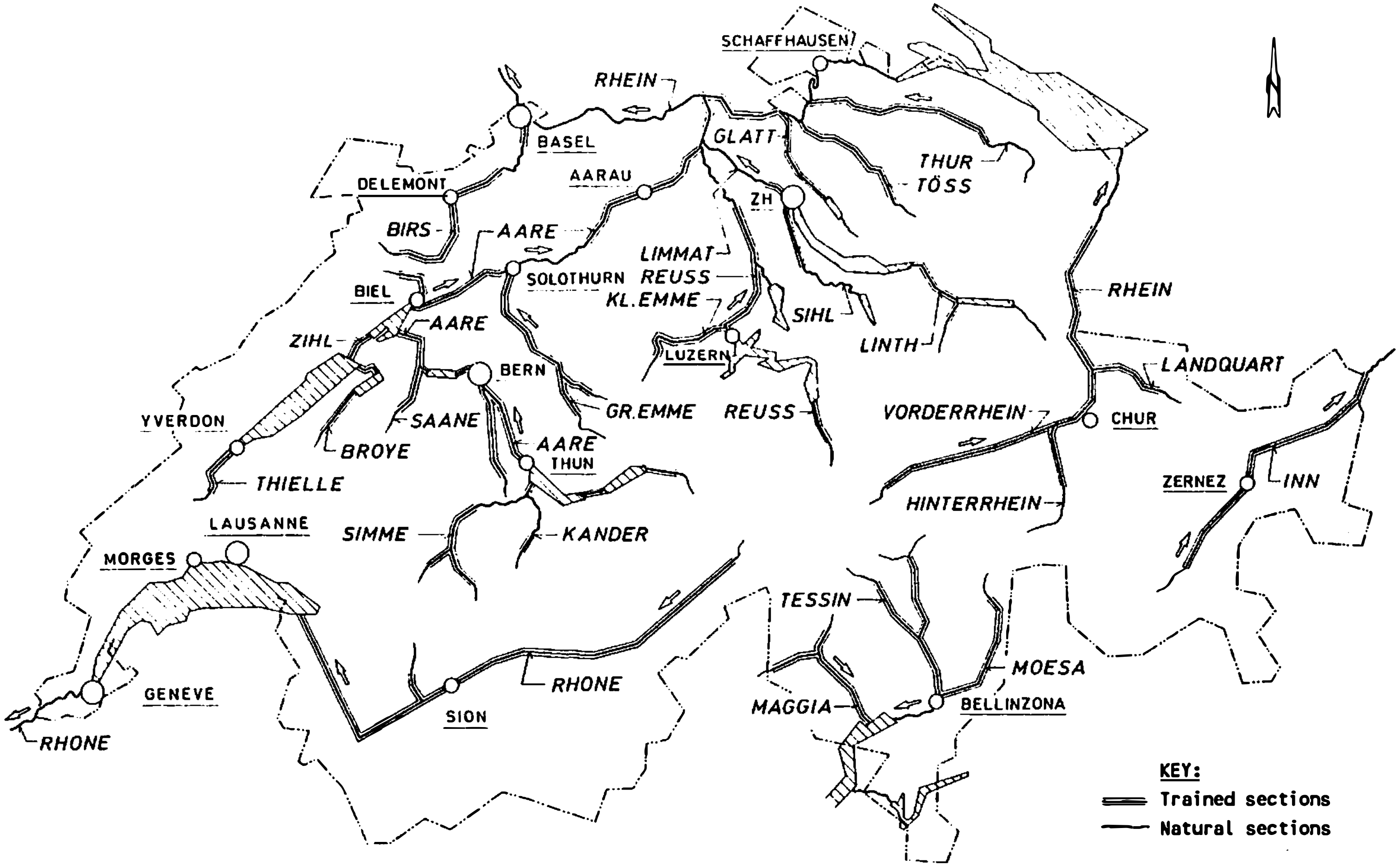


Illustration 51: *Lifting gate: eight inch oak beam connected with steel clamps. Operated by chain and lever. According to Bauernfeind 1866.*

SWISS WATER TRAINING IN THE 18th AND 19th CENTURIES



5. Other River Training Projects

In this volume, only the training of the Kander, the Linth and the first Jura training have been described. As already mentioned in the section 1, it is important for full comprehension of Swiss river control to present these river training schemes within the history of Swiss hydraulic engineering in order to arrive at an overall picture. Illustration 52 gives an idea of the abundance of these schemes.

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