

## **Flood protection by re-establishment of the flood plains along the Upper Rhine**

### **The Integrated Rhine-Programme of the Land Baden-Württemberg**

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The aim of the Integrated Rhine Programme is the re-establishment of the flood protection along the Upper Rhine in connection with the restoration and preservation of the flood plains of the Rhine. Because of the canalization of the Upper Rhine until the end of the seventies of this century, the danger of floods along the section of the Rhine downstream of Iffezheim has increased considerably. The Federal Republic of Germany and the French Republic therefore agreed already in the year 1982 to re-establish the flood protection existing before the canalization of the Upper Rhine. To achieve this aim, measures in France, Baden-Württemberg and in Rhineland-Palatinate are required. For the measures in Baden-Württemberg the Integrated Rhine Programme was conceived.

#### **1. Starting point**

In the Treaty of Versailles France was given the right after the Second World War to take water out of the Upper Rhine and to use the water-power obtained by the canalization of the Rhine. From 1929 until 1959 France has constructed the Rhein-Seitenkanal (side channel of the Rhine) between Märkt and Breisach with the barrages of Kembs, Ottmarsheim, Fessenheim and Vogelgrün. Between the years 1959 and 1970 the Upper Rhine has been more built up in the form of 4 Rhine-loops between Breisach and Straßburg with barrages at Marckolsheim, Rhinau, Gerstheim and Straßburg. Afterwards, until the year 1977, the barrages Gamsheim and Iffezheim in the main Rhine were completed as the last barrages for the present. (illustration 1).

Direct consequence of the construction of the barrages is the loss of about 130 km<sup>2</sup> or of about 60 % of the formerly flooded surfaces and a considerable increase in the danger of floods downstream from the built-up section. Apart from the heightening of the peak of the Rhine-wave as a result of the lost flooded areas the quicker draining away of the whole wave determined by the canalization and its unfavourable coincidence with the tributaries has increased mainly the danger of floods.

The international „Hochwasser-Studienkommission für den Rhein“, set up in the year 1968, has examined the effects of the canalization of the Upper Rhine and has obtained the following result:

„Before the construction of the barrages the area of Karlsruhe (water depth gauge Maxau) was protected against a flood occurring every 200 years and the area of Mannheim/Ludwigshafen (water depth gauge Worms) against a flood occurring every 220 years. This was corresponding to a protection against a draining away of up to 5000 m<sup>3</sup>/s at the water depth gauge Maxau and up to 6000 m<sup>3</sup>/s in Worms. In consequence to the construction of the barrages the same drains of high waters are now occurring in the statistical average already every 60 years. At the actual state of construction flood events occurring every 200 years would reach without the already operational retention measures 5700 m<sup>3</sup>/s at the water depth gauge Maxau and 6800 m<sup>3</sup>/s at the water depth gauge of Worms. As the capacity of draining away at the water depth gauge Maxau is only 5000 m<sup>3</sup>/s and in Worms 6000 m<sup>3</sup>/s, there may occur quite often breaches in dykes with considerable damages.“

Correspondingly, the aim of the measures for protection against floods along the Upper Rhine is to reduce the peak of the critical event at the water depth gauge Maxau by 700 m<sup>3</sup>/s and at Worms by 800 m<sup>3</sup>/s (table 1).

## **2. Existing danger of flood along the Upper Rhine**

The section of the Rhine between Basel and Iffezheim has today a almost 100 % flood protection because of the canalization. The section bordering in the North of Iffezheim until about the mouth of the Main is still in most parts in that state as it was created by the correction of the Rhine by Tulla and the following measures in the last century. There is nowadays existing only a protection against events occurring about every 90 to 100 years. Directly after the completion of the canalization of the Rhine in the year 1977 the flood protection downstream from the built-up section has even gone back to an event occurring about every 60 years. The nowadays again improved flood protection along this section of the Rhine is a result of the creation of retention areas upstream from Iffezheim so far.

But the today existing flood protection downstream from Iffezheim is still absolutely insufficient. Before the canalization of the Rhine there was given a protection against floods occurring every 200 years (in the area of Karlsruhe) and against floods occurring every 220 years (in the area of the mouth of the Neckar/Worms). Furthermore the ground behind the dykes in this section of the Rhine has been used extremely expansively in the last decades. Settlements, industrial areas and the establishment of infrastructure were extended nearer and nearer to the Rhine, so that today enormous material assets are existing behind the dykes. The potential of danger along the Upper Rhine downstream of Iffezheim, that can be valued monetarily, is estimated to be much over 10 billion DM.

An improved flood protection for this section of the Rhine is also therefore of great importance as the main dykes of the Rhine are only set up on the natural ground. If these dykes, for example as a result of the sure overflow in case of big high water events are breaching, the water can flow into the relatively flat land of the Upper Rhine Plain and can cause severe damages and risks there

The Lands Baden-Württemberg, Rhineland-Palatinate and Hessen as downstream-neighbours have therefore demanded that the security against floods existing before the canalization of the Rhine has to be re-established. To achieve this aim, which has been layed down in the agreement between the Federal Republic of Germany and the Republic of France in the year 1982 concretely for the water depth gauge of Karlsruhe/Maxau and Worms, 212 million m<sup>3</sup> of controlled retention area were required according to the calculations made at that time. 56 million m<sup>3</sup> of them were supposed to be created by France, 30 million m<sup>3</sup> by Rhineland-Palatinate and 126 million m<sup>3</sup> by Baden-Württemberg (table 2).

### **3. Possibilities of the high water retention along the Upper Rhine**

Along the Upper Rhine retention areas can be created by weirs, polders, moving back of dykes and by the special operation of the water-power-stations of the Rhine („manoeuvre“).

#### **3.1 Weirs**

With the weirs in the Rhine, like for example the existing cultural weirs of Kehl and Breisach, the water level in the bed of the Rhine and also in the flooded areas can be controlled on the upstream side. For the flood retention the weirs operate according to a fixed rule. In case of weirs with a permanent retention of water this happens by emptying the retention area in advance with building-up the retention again, in case of weirs with free flow of water by a build-up. The height of the retention depends on the construction of the weir, on the position of the locks of the weir and on the flow of water at the weir. In this way the surface of the water in the area between the highest and the lowest position of the locks of the weir can be influenced. The retention volume that can be achieved by a weir depends therefore on the flow of water at the weir and cannot be used with a complete maximum in the case of every flood. Weirs can be used specifically and with a great effectiveness for the flood protection, as the wave of the flood can be reduced at the planned time and with the best possible retention, especially around the peak of the flood

#### **3.2 Polders**

Polders are retention areas beside the Rhine which can be flooded artificially by constructions of entry. For the flood retention the polders operate according to a fixed rule, what can reduce the peak of the high water wave in a purposeful way. The maximum retention volume achievable by a polder depends on the area that can be flooded, the ground-relief including eventual obstacles of drain, the water-levels in the Rhine at the entrance and the capacity of the construction of entry.

Is the construction of entry situated in the upper area of a retention or in the free section of the Rhine, where the water-level depends on the draining away of the Rhine, the flooding of the polder is determined decisively by the draining away of the Rhine. Is the construction of entry on the other hand situated nearer to the barrage, the area of the polder can be flooded more or less regardless of the event. As

the time of the operation and the extent of the high water retention can be controlled widely, polders can operate like weirs purposefully and can be used with a great effectiveness.

### **3.3 Special operation of the power-stations of the Rhine („manoeuvre“)**

Along the section of the canalization between Basel and Strasbourg the draining away of the Rhine by the power-stations is divided, in fact between Basel and Breisach into the side channel of the Rhine and into the Rhine, as well as between Breisach and Straßburg in sections into the Rhine and into the four loops. While the side channel of the Rhine is situated at its whole length alongside the Rhine, in the areas of the 4 loops channels are existing only in parts beside the Rhine, so that there are rest sections of the Rhine, where the whole draining away of the Rhine is flowing through. On the sections of the Rhine beside the channels the flow is reduced by the amount of water needed for the operation of power-stations and floodgates.

In the case of the special operation of the power-stations of the Rhine the flow through the channels of the power-stations is reduced considerably or completely stopped and given away to the Rhine. Because of this, the draining away rises in the „Restrhein“ and together with them the water-levels in the bed of the Rhine and eventually in the bordering flooded areas. In this way additional retention volume is created which can be used specifically for the flood protection. Because of the possibility of controlling, the special operation of the power-stations of the Rhine can be used purposefully and with a great effectiveness. In its effects it is comparable to the polders and weirs.

### **3.4 Moving back of dykes**

Moving back of dykes means to replace an existing dyke towards the inland to create new surfaces which are flooded in a natural way by the Rhine. This is only possible on the free section of the Rhine downstream from Iffezheim as well as in the area south of the cultural weir of Breisach in the case of putting lower the formerly naturally flooded meadows.

The volume, achievable by the moving back of dykes, depends on the surface of the additional flooded ground, on the ground-relief and on the height of each flood that is determined by the draining away of the Rhine. The flooding is not controllable, so that the retention volume cannot be used specifically. In that way the whole rising flood-wave is reduced, not a chosen part of it. The flood wave is displaced mainly in a parallel way and therefore its drain is delayed in time.

From the ecological point of view moving back of dykes is the best solution, as they re-establish the natural dynamic of flooding. They correspond to the formerly existing state and offer therefore the best conditions for the restoration of the meadows. In addition they require considerably less artificial constructions and also do not need any control. However, the disadvantage is, that they need much more surface than polders or weirs to achieve the same effect of flood protection.

## **4. The Integrated Rhine Programme of the Land Baden-Württemberg**

### **4.1 Basis**

The Integrated Rhine Programme assumes that all flooded surfaces along the Rhine existing before the canalization have to be taken into consideration for an extensive concept of flood protection. No longer achievable retention areas are foreshores which are already now flooded. But also the old meadows (former flood plains) situated behind the main dykes of the correction of the Rhine by Tulla are not suitable for flooding them again, because of today's structures of use. The examinations for the preparation of sufficient retention area within the frame of the Integrated Rhine Programme is therefore reduced, apart from one exception, to the foreshore areas, which have been flooded at least from time to time after the correction of the Rhine by Tulla.

The right of the conservation of nature in force and the legal obligations for the assessment of environmental impact require to take the effects of flooding on the nature and the landscape into consideration, to avoid damages as much as possible. An environmentally friendly flood protection therefore requires that ecosystems which are tolerant towards high waters are preserved in the retention areas or that the conditions for their re-establishment are created. If it should concern in this case, corresponding to the aims of the Integrated Rhine Programme, meadow landscapes which are typical for the Rhine, nature-like floodings are required with the greatest possible extent of connection to the dynamic of the Rhine. For the restoration of the alluvial meadow and for the adaption of the communities the Integrated Rhine Programme is determined to recreate conditions typical for the flood plains by „ecological floodings“ and „flows through the retention areas“. Additionally the variations of the ground water levels which are typical for the flood plains and the soil transfers determined by the drains should be restored or permitted again as far as possible.

The ecologically-founded demand, not to flood alluvial biotopes that are existing or to be re-established too high and too long and to avoid standing water, excludes for all areas that are taken into consideration for the restoration of flood plains, the setting-up of the so called „pocket polder“, that means retention areas with a high retention level and standing water. Along the section of the canalization every area which is suitable for the re-flooding for flood protection must be used. For a restoration of the flood plains other areas are not available there.

Because of the experiences in the realization of the conception, as it resulted from the agreement concluded in 1982, as well as in the case of operations of the already completed polders Altenheim and the cultural weir Kehl/Straßburg, the following principles have been fixed in the new conception for the Integrated Rhine Programme in 1988, which have to be carried out in the case of the retention areas that are still to be created:

- The retention areas, so the former flood plains, should not only be flooded if necessary in the case of floods, that means every 10, 20 or 30 years several metres, as otherwise the communities existing there today and which are mostly adapted to more dry local conditions, will be damaged.
- In the flooded areas communities typical for the flood plains have to be developed, which survive the high water floodings largely without any damage
- Requirement for the development of communities typical for the flood plains is, that the areas are set under water in a natural regularity and with a suitable height and that standing water is largely avoided.

Those inevitably occurring regular floodings, so the ecological floodings, are according to that the basis for the restoration of the former flood plains. They should begin in the case of drains of the Rhine at about 1550 m<sup>3</sup>/s with a few m<sup>3</sup>/s and should start therefore a long time before the beginning of the flood retention. With a rising draining away in the Rhine also the amounts of water from the Rhine will be increased, so that the floodings in the retention areas correspond as much as possible to those of the former natural floodings. The areas should only be flooded at a little height. Taking out of drains of the Rhine below 1550 m<sup>3</sup>/s is only possible in a relatively small extent, as those drains are, on the basis of the Treaty of Versailles, to their greatest extent reserved for the use of the power-stations. The high water retention starts - depending on the location - at drains of the Rhine between about 3000 and 4200 m<sup>3</sup>/s.

The consequence of the keeping of these principles is that much more retention areas and therefore also more surfaces will be required than originally planned. Also the retention volume, that is necessary for the achievement of the aim of the flood protection downstream from Iffezheim together with the measures in France and in Rhineland-Palatinate, has therefore become considerably larger (table 2).

With the now 13 required retention areas all surfaces on the side of Baden-Württemberg between the Rhine and the old dykes of Tulla which are practically available, are included into the flooding events of the Rhine

#### **4.2 Retention areas in Baden-Württemberg**

The frame concept of the Land Baden-Württemberg for the realization of the Integrated Rhine Programme includes 13 locations between Basel and Mannheim (Illustration 2).

Along the constructed section of the Rhine from Breisach to Iffezheim 2 weirs and 7 controlled retention areas are planned.

In the most southern retention area, where the Rhine has carved itself up to 7 m into the ground after the correction by Tulla, is alternatively a weir or the putting lower of the bordering grounds with a following free flooding possible, what corresponds in its effects to a moving back of dykes.

In the case of two other retention areas downstream of the built-up section, where the need for retention referring to the water depth gauge Worms is lower, a polder or a moving back of dykes are alternatively possible. Furthermore a controlled retention area is planned there.

Because of the barrages between Breisach and Iffezheim, where the Rhine is dammed up to 8 m upon the ground there is no moving back of dykes possible. Because of this, there are only weirs and polders planned, but only in keeping the above represented ecological principles, especially the ecological floodings.

The two weirs of Breisach and Kehl are completed. As there is a permanent retention kept for supporting the ground-water and as they serve therefore for landcultural purposes, they are called cultural weirs. But the cultural weir of Breisach cannot yet be used for the flood retention. Also completed and ready for use are the polders Altenheim one and two.

#### 4.3 Actual state of realization

The following constructions and measures of the measures for flood protection fixed in the agreement between the Federal Republic of Germany and the Republic of France in the year 1982 are ready for use:

Special operation of the power-stations of the Rhine (France).	45,0 million m <sup>3</sup>
Polder Moder (France):	5,6 million m <sup>3</sup>
Polder Altenheim (Baden-Württemberg):	17,6 million m <sup>3</sup>
Cultural weir Kehl/Straßburg (Baden-Württemberg):	<u>12,0 million m<sup>3</sup></u>
	80,2 million m <sup>3</sup>

The cultural weir of Kehl/Straßburg is at the moment only usable with a reduced retention and a volume of about 12 million m<sup>3</sup>. Only after the completion of the measures of adaption on the side of the inland to limit the heightening of the ground-water in the case of an operation of the cultural weir, the retention volume of 37 million m<sup>3</sup> permitted in the planning is totally operational. The completion of these works is expected for 1998/99

With these measures a protection against high waters occurring about every 90 to 100 years can be guaranteed for the section of the Rhine downstream from Iffezheim until about the mouth of the Main.

For three other areas in Baden-Wurttemberg - the cultural weir of Breisach, the polder Breisach/Burkheim and the polder Söllingen/Grefferen - together about 28 million m<sup>3</sup> the procedures of the environmental plannings are completed. For those areas the documents for the planning permission are at the moment in preparation. For the polder Söllingen/Grefferen the planning permission hearings are initiated probably in the 1st semestre of 1997.

The documents of permission for the areas Wyhl/Weisweil and Elzmündung with a retention volume of about 13 million m<sup>3</sup> together are also in preparation at the moment.

### **5. Effects of the flood retention along the Upper Rhine**

The operation of all retention measures along the Upper Rhine is set for the directly following section of the Rhine Karlsruhe-Speyer-Mannheim-Worms. This corresponds to the international agreements that have been reached. With the help of a model of the draining away of the high waters calibrated at the natural draining away of the Upper Rhine it has been proved, that the determined operation of all planned flood retention measures along the Upper Rhine on the basis of assessment for high waters leads to the necessary reductions of the peaks by 700 m<sup>3</sup>/s in the area of Karlsruhe and by 800 m<sup>3</sup>/s in the area of Worms. This reduction of the draining away corresponds to a lowering of the water-level of about 50 - 55 cm on this section of the Rhine. The effect is kept almost until the mouth of the Main because of the low number of tributaries.

More downstream of the Rhine this effect is getting smaller and smaller, as the Main, Nahe, Mosel, Lahn and Sieg are tributaries which flow into the Rhine and which have also a high draining away of high waters, so that they meet with this lowering of the water-level and cancel each other out. In this way, it was possible by the high water operation of the cultural weir of Kehl/Straßburg and the polder Altenheim with together about 25 million m<sup>3</sup> to lower the high water peak in Karlsruhe/Maxau by 23 cm during the flood in March 1988. In Mainz it was only possible to prove a reduction of the peak by 6 cm and in Köln by 3 - 5 cm.

### **6. Costs and completion**

The pure investment costs for the construction of the 13 retention areas in Baden-Württemberg is at present estimated to be around 700 million DM. Of these there have already been 150 million DM spent for the building of the cultural weir Kehl and the polder Altenheim. To these costs there have to be added the costs of planning and examination, the costs for personnel as well as payments of compensation, especially for the limitation of use in the retention areas. The Federal Republic of Germany contributes to the greatest part of the expenses for the Integrated Rhine Programme with 41,5 %. The resting 58,5 % and the other costs, particularly also the costs of operation, are chargeable by the Land Baden-Württemberg.

Because of the experiences so far made concerning the execution of the procedures of permission and because of the following period of construction which takes several years the last retention area in Baden-Württemberg cannot, on the basis of the actual state, be completed before the year 2010. This requires that the financing based on this time target can be kept up in the main till the end.



### **Literature**

- (1) Hochwasser-Studienkommission für den Rhein: Schlußbericht, Bundes-ministerium für Verkehr, Bonn, 1978.
- (2) Vereinbarung zur Änderung und Ergänzung der Zusatzvereinbarung vom 16. Juli 1975 zum Vertrag vom 4. Juli 1969 zwischen der Bundesrepublik Deutschland und der Französischen Republik über den Ausbau des Rheins zwischen Kehl/Straßburg und Neuburgweier/Lauterburg vom 6. Dezember 1982, BGBl. 1984 II S. 268 ff.
- (3) Umweltministerium Baden-Württemberg: Der Oberrhein im Wandel, Heft 9, Veränderungen der Auelandschaft am Oberrhein, 1993.
- (4) Umweltministerium Baden-Württemberg: Der Oberrhein im Wandel, Heft 11, Rahmenkonzept des Landes zur Umsetzung des Integrierten Rheinprogramms, 1994.

### **Zusammenfassung:**

Ziel des Integrierten Rheinprogramms ist die Wiederherstellung des Hochwasser-schutzes am Oberrhein in Verbindung mit der Renaturierung und Erhaltung der Rheinauen. Durch den Ausbau des Oberrheins bis zum Ende der siebziger Jahre dieses Jahrhunderts ist die Hochwassergefahr auf der Rheinstrecke unterhalb von Iffezheim wesentlich verschärft worden. Die Bundesrepublik Deutschland und die Republik Frankreich haben daher bereits im Jahr 1982 vereinbart, den vor dem Oberrheinausbau vorhandenen Hochwasserschutz wieder herzustellen. Um dies zu erreichen, sind Maßnahmen in Frankreich, in Baden-Württemberg und in Rheinland-Pfalz erforderlich. Für die in Baden-Württemberg erforderlichen Maßnahmen wurde das Integrierte Rheinprogramm konzipiert.

### **Summary:**

The aim of the Integrated Rhine Programme is the re-establishment of the flood protection along the Upper Rhine in connection with the restoration and preservation of the flood plains of the Rhine. Because of the canalization of the Upper Rhine until the end of the seventies of this century, the danger of floods along the section of the Rhine downstream from Iffezheim has increased considerably. The Federal Republic of Germany and the French Republic therefore agreed already in the year 1982 to re-establish the flood protection existing before the canalization of the Upper Rhine. To achieve this aim, measures in France, Baden-Württemberg and in Rhineland-Palatinate are required. For the measures in Baden-Württemberg the Integrated Rhine Programme was conceived.



Illustration 1: Ground plan of the barrages along the Upper Rhine

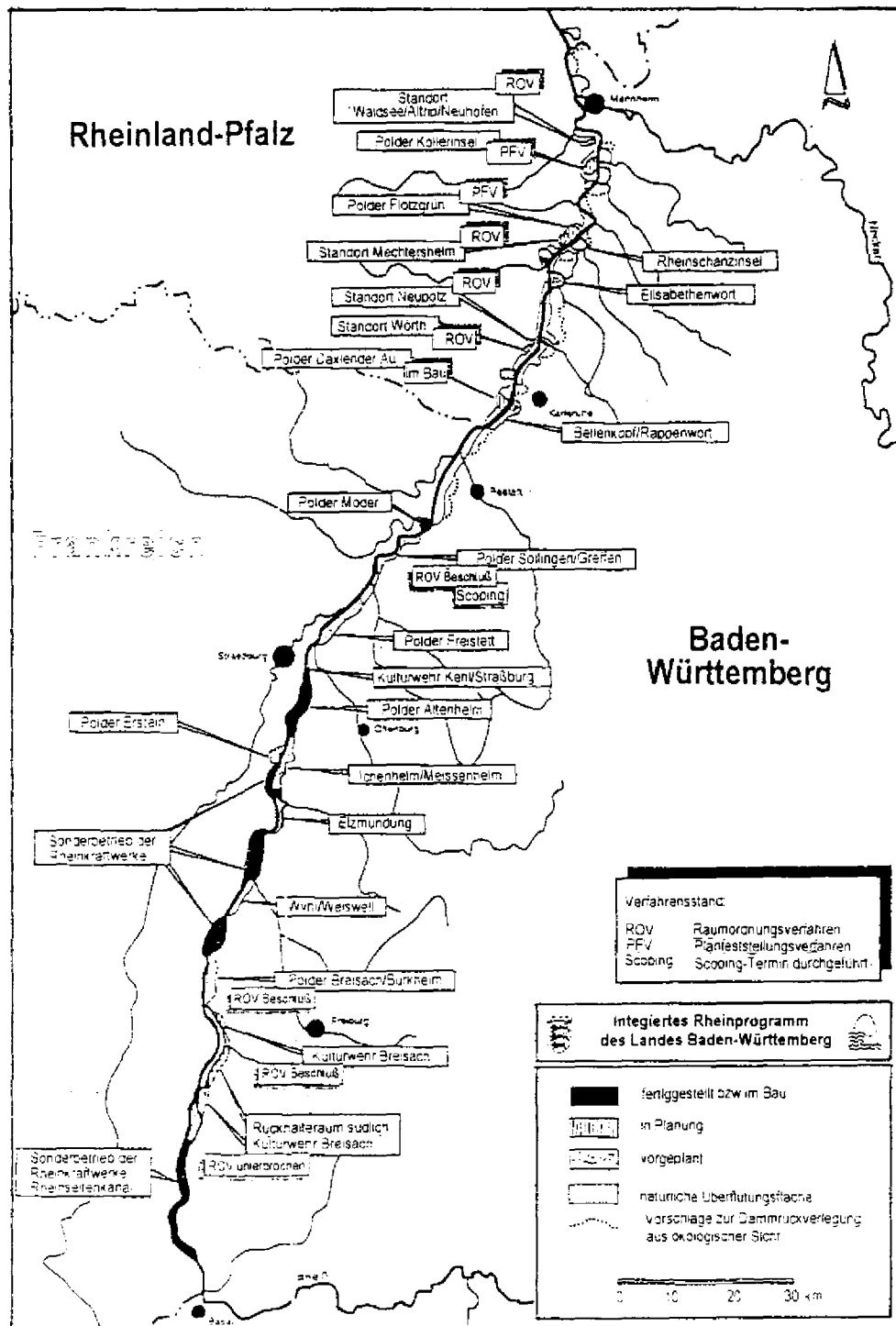


Illustration 2: Ground plan of the retention areas along the Upper Rhine in Baden-Württemberg

**Table 1: Change of the high water drains at the water depth gauges of Karlsruhe/Maxau and Worms in consequence to the canalization of the Upper Rhine**

	Water depth gauge Karlsruhe/Maxau	Water depth gauge Worms
Capabilities of the bed of the Rhine (= in years before the canalization)	5000 m <sup>3</sup> /s (= HQ 200)	6000 m <sup>3</sup> /s (= HQ 220)
Draining away occurring every 200 or 220 years (before canalization, 1955)	5000 m <sup>3</sup> /s	6000 m <sup>3</sup> /s
Draining away occurring every 200 or 220 years (after canalization, 1977)	5700 m <sup>3</sup> /s	6900 m <sup>3</sup> /s
	↓	↓
Heightening of the high water peak	700 m <sup>3</sup> /s	800 m <sup>3</sup> /s

**Table 2: Retention measures along the Upper Rhine according to the concept of 1982 and the concept of today**

Retention area	Type of retention	Volume [million m <sup>3</sup> ]	
		According to the concept of 1982	According to the actual concept
<b>Baden-Württemberg:</b>			
South of the cultural weir of Breisach	weir or putting lower of the foreshores	53	25,0
Cultural weir Breisach			
Breisach/Burkheim	weir	10	9,3
Wuhl/Weisweil	polder	-	6,5
Elzmündung	polder	-	7,7
Ichenheim/Meißenheim	polder	-	5,3
<i>Altenheim</i>	polder	-	5,8
<i>Cultural weir Kehl/Straßburg</i>	<i>polder</i>	<i>18</i>	<i>17,6</i>
Freistett	<i>cultural weir</i>	<i>37</i>	<i>37,0</i>
Sollingen/Grefferen	polder	-	9,0
Bellenkopf/Rappenwört	polder	8	12,0
	polder or eventually moving	-	14,0
Elisabethenwort	back of dykes		
	polder or eventually moving	-	11,9
Rheinschanzinsel	back of dykes		
	polder	-	6,2
<b>Subtotal Baden-W.</b>		<b>126</b>	<b>167,3</b>
<b>France:</b>			
<i>Special operation of the power-stations of the Rhine</i>		<i>45</i>	<i>45</i>
Erstein	polder	6	7,8
<i>Moder</i>	<i>polder</i>	<i>5</i>	<i>5,6</i>
<b>Subtotal France</b>		<b>56</b>	<b>58,4</b>
<b>Rhineland-Palatinate</b>		<b>30</b>	<b>30</b>
<b>Total</b>		<b>212</b>	<b>255,7</b>

In italics: operational retention measures, about 12 million m<sup>3</sup> of these at the cultural weir Kehl/Straßburg