# Expert opinion on the use of the AMPHIBEX type of floating dredgers for icebreaking on the Odra River

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Amphibex dredgers are manufactured by Normrock, a Canadian company, in several versions differing in size and range. For almost 30 years, they have been used to crush ice and eliminate ice jams, mainly on the rivers in the provinces of Manitoba and Quebec in Canada and in the northern part of the United States. Amphibex uses its high weight to crush the ice, while in the case of the jam elimination, ice crushing and removal takes place by means of an excavator. The main advantage of these machines is that they reach the workplace easily and have little or no impact on the environment. There are also no limitations in the context of the required water depth. The disadvantage is the slow work on the ice breaking and the lack of possibility of linear operation to form a clearance for the runoff channel for the crushed ice.


*Gdansk, 23rd of August 2018*

# 1 Technical Specification of AMPHIBEX 400

Amphibex 400 from Normrock Industries Inc. is the smallest series-produced dredger and adapted to the operation in ice. It has got the maximum length of 10.85 m and the weight of 22 tonnes. The hull consists of nine interconnected modules. The speed on the water is from 5 up to 8 knots and it is driven by a six-cylinder 261 Kilowatts diesel engine. The working range of the excavator arm is 6 metres deep into the water and up to 8 meters of horizontal reach within 170° angle range. Some of the dimensions are shown in the Figure 1, and their combination is given below.

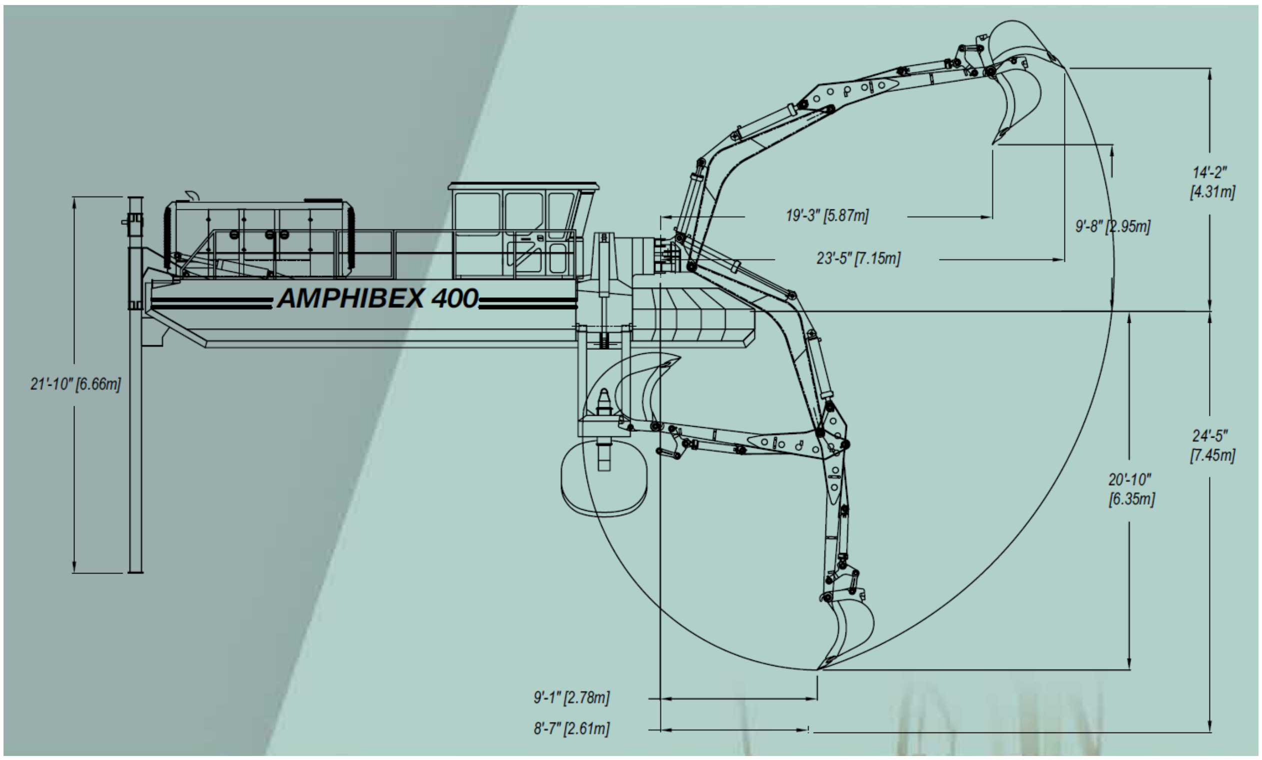



Figure 1. Technical drawing of the Amphibex 400 dredger from the Normrock Industries Inc. brochure.

## 1.1 Technical Specification of the AMPHIBEX 400 dredger, according to Normrock.ca

<u>DIMENSIONS:</u>

Length of the operating unit: 10.85 m
Total weight of the operating unit approx. 22 tonnes
Length of the unit during transport on a trailer 12.85 m
Width of the unit during transport on a trailer: 3.5 m
Height of unit during transport on a trailer: 3.2 m (10’ 6")
Speed on water: 5 to 8 knots

ENGINE: C9 ACERT CATERPILLAR

6 cylinders
Maximum power: from 275 to 375 HP
Max. torque for 275 HP: 1225 Nm at 1400 rpm
Max. torque for 375 HP: 1667 Nm at 1400 rpm

HYDRAULIC SYSTEM

Maximum operating pressure: 450 bar
Hydraulic system output: 500 L (132.09 Gal.)
(hydraulic oil made of biodegradable vegetable base)
Electrical system: 12 volts or 24 volts
Batteries (2): 1000 A
Fuel tank: 1200 L

EXCAVATOR

Excavation radius: from 6.6 m to 7.86 m at 170°.
Excavation depth (with telescopic indicator): 6.5 m
Bucket turn power: various options available
Attack excavator power: various options available

PRICE

Approximately 1.2 million Canadian dollars (approximately PLN 3 400 000)

Among other models, the Amphibex 400 is the most frequently used for crushing ice. The first tests were carried out on the rivers in the province of Quebec in the late 1980s. After recognising the advantages of these machines, they began to be used regularly from 1989 on the Rideau River (average flow of 35 $m^3/s$) and the DuLoup River (100 km tributary of the St. Lawrence River). They were then used in the northern states of the USA (Maine, Vermont, New York) and in the provinces of Manitoba, Quebec and Ontario in Canada, among others, on the Red River (average flow in the estuary of 244 $m^3/s$). Amphibex machines are most often used on small rivers with a high jamming potential and difficult to reach for other units or heavy equipment.

These machines are used both to prepare an ice-free trough in the ice cover and to remove ice jams. In the first case, the operation of a dredger consists in dragging a heavy pontoon over the ice cover, which due to its high weight, breaks the ice. Removal of jams is carried out similarly to the work on demolition of buildings, i.e. by crushing ice fragments by an excavator, which then flow down the river.

The great advantage of the dredgers is their high mobility and ease of delivery to any place of work. The equipment is transported to the workplace on a trailer from where it is brought to the river bank. The dredger rises on movable supports and front stabilisers, and a trailer can then easily leave from under it. Then, using its supports, the dredger is brought onto the water or ice with a walking motion (see Figure 2).

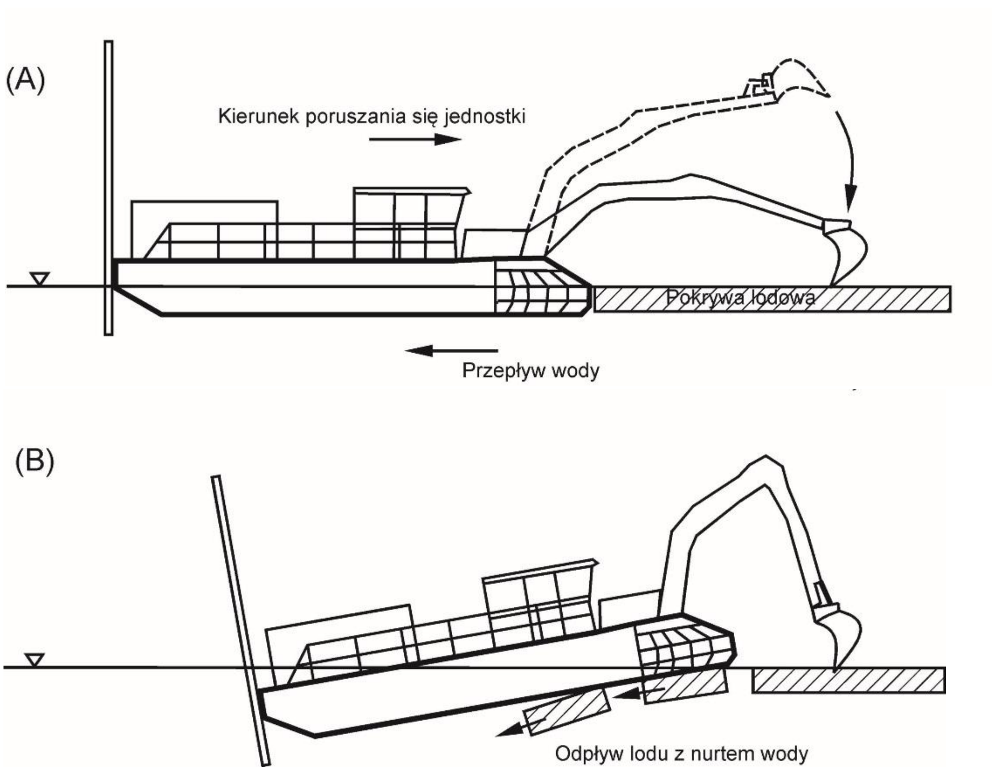

Figure 2. Unloading stages of the Amphibex 800 dredger (solution analogous to the Amphibex 400)

## 1.2 Operation of the AMPHIBEX 400 dredger at crushing the ice cover

Icebreaking is always carried out in the situation of predicted ice run, when the remaining ice cover is weakened by high air temperatures (above 0°C) or rainfall. The aim of the icebreaking action is always to clear the river and prepare it for ice runoff. This is usually done by making an ice runoff channel in the ice cover, which must be wide enough as not to stop the ice float during the runoff. The work of the Amphibex dredgers leads to the same effect, while the technique of making the trough free from ice differs slightly from that used in classic icebreakers.

Crushing of the ice cover takes place as a result of placing a 22-tonnes pontoon on the ice, which causes the cover to crack. The operation of the unit is carried out analogously to classic icebreakers, i.e. against the current of the river, which allows the crushed ice to flow downstream. Moving the unit on ice is done by pulling the pontoon on the arm of the excavator onto the ice cover (Fig. 3A). The use of front stabilisers is necessary due to possible large heels. As the result of applying high weight force to the weakened ice cover, the ice cover will crack and the flowing water ensures that the crushed ice will flow away. This is a slow process, and with an experienced operator it is possible to make progress at the speed not higher than 0.5 km/hour (usually 300-400 m/hour).

**Unit motion direction →**




**Ice cover**

**← Water flow**

**Ice runoff with water current**

Figure 3. Operating diagram of the Amphibex dredger at crushing the ice cover

Figure 4. Amphibex in operation on the Red River between Natley Lake and Selkirk in the Manitoba Province, March 2014.

The width of the ice-free channel thus constructed will vary from 4 m (the width of the Amphibex 400 pontoon is 3.5 m) up to 7 m, which will depend on the properties of the ice. This means that in order to make a 10 m wide trough, two machines will be required, which during 8 hours of work will be able to make an ice-free channel not longer than 10 km. Of course, the progress of work will largely depend on the thickness of the ice cover on which it will work, the amount of the water-current ice underneath it and the speed of the water flow. In the case of a very thick cover, it is possible to cut it earlier with combustion saws, which significantly prolongs the whole process. The observations of the Amphibex units' operation in the ice show that it is very laborious and requires several approaches to the same part of the ice cover, thus resulting in a very slow progress of work.

According to the literature (CREEL Report 98-14), a single Amphibex dredger is capable of crushing 0.16 hectares of ice per hour. This applies to a smooth ice cover from 40 to 50 cm thick, without soffits and loose snow. The work progress is very slow compared to conventional icebreakers, which are capable of more than twenty times greater efficiency (more than 3 ha/hour).

As people from Normrock emphasise (contacted directly), the Amphibex machines are most often used for the preventive preparation of the river for ice runoff (the procedure has been described above). The operation is carried out by 2 to 3 units working for 4 to 6 weeks, immediately prior to the predicted ice run. The work is usually carried out 24 hours a day, which results in the construction of a runoff channel with the width of 30 up to 100 m.

## 1.3 Operation of the AMPHIBEX 400 at removal of ice jams

Removal of ice jams is the greatest challenge for any type of icebreaker or other technical means. A jam is an accumulation of broken ice fragments, chaotically arranged in the river bed, causing difficulties in the outflow of water, resulting in a build-up of water above the jam. The location and duration of the jam are very difficult to predict. As the result of observations of historical phenomena, potential places predisposed to stop the ice run-off can be obtained. However, taking into account the multitude of factors favouring jams, it turns out that the jams on rivers may form in sections of several kilometres. Based on the example of the Odra River one can indicate at least 40 locations (data from the RZGW *[Regional Water Management Board]* Wrocław) between Brzeg Dolny (km 281.6) and Krosno Odrzańskie (estuary of Nysa Łużycka at km 542.4) over the total length of more than 80 km (almost one third of the considered river length). With such a high jam potential of the Odra River, one should expect that the jams on the central Odra River may form along its entire length, which poses a serious challenge to the services responsible for the management of this section of the river.

Ice jams on the Odra River, which is under the management of RZGW *[Regional Water Management Board]* Szczecin, are most often formed in the locations presented in the PROEKO Report, 2003: "Clearance of the fairway on the Lake Dąbie, Feasibility study of the investment". The most frequently, ice jams are observed in the following locations: Widuchowa (km 704); Ognica (km 697); Krajnik (km 689); Piaski (km 682); Bielinek (km 673); Osinów (km 663); Gozdowice (km 645); Szumiłowo (km 621); Górzyca (km 605); Słubice (km 584). On the basis of the available information, several causes of ice jam formation on the Odra River can be listed.

1. Impact of the sea backwater observed even up to Gozdowice (km 645)
2. Wind blowing from the direction opposite to the direction of the flow; a problem particularly important for the Lake Dąbie but also in any other location
3. Change of the river stream direction (e.g. for km 673 Bielinek)
4. Narrowing of the river bed (e.g. Bielinek or Widuchowa)
5. Stopping of ice run-off on pillars of bridge structures located in the river stream (e.g. Słubice)
6. Shallowing occurring in the river stream arising as the result of depositing of rubble; in the absence of dredging works carried out and poor quality of the control equipment the problem applies to almost the entire section of the Odra River.
7. Ice supply to the Odra from the left-hand tributaries (e.g. Gozdowice or Ognica)

The issues mentioned in the paragraphs 1 and 2 are impossible to eliminate. Paragraphs 2 and 3 are related to the hydrographic system of the Odra River, which to some extent can be corrected by regulation works. Other causes can be minimised by appropriate hydrotechnical works.

Removal of jams first of all consists in clearing the bed as soon as possible in order to unblock the accumulation of water. Regardless of all factors, jam removal should be carried out from the front of the jam. If the jam is supported by the ice cover in the lower course of the river, then the works begin with crushing the ice cover and running off the ice down the river. This is done by cutting out an ice-free trough of sufficient width to run off the ice accumulated in the jam. Then (or in parallel) a trough of the same width is made in the jam starting from the front of the jam. Once such a trough has been made, an increase in the flow of water that has been trapped by the jam can be expected. Both the trough in the jam and the one made in the cover below the jam should be widened and constantly monitored so as not to cause another jam freshet from the flowing ice. On the Odra River, front icebreakers - the most powerful units -

are used to form an ice trough, while linear icebreakers - planned to be built for the needs of the RZGW *[Regional Water Management Board]*Szczecin - are used to expand and monitor the troughs.

Based on the direct communication with the employees of Normrock Industries Ltd. as well as scientific publications and film materials, I can say that the Amphibex dredgers can be used for front works in the ice jams. Before operating these units in very difficult field conditions, it will be necessary to thoroughly train the crews, preferably in cooperation with the manufacturer. Work of dredgers in jams is not a common practice but such works were carried out on rivers in Canada.

Figure 5: Removal of jam on the Charteauguay River in the Quebec Province, 4th of March 1995 (photos taken onboard the unit).

One of the better described icebreaking operations by the Amphibex dredgers is the operation on the Kaministiquia River in the province of Ontario in March 2006. The Kaministiquia River is a small direct tributary of the Lake Superior. The average flow during the winter months does not exceed 50 $m^3$/s and in March it is 47 $m^3$/s. In the winter season of 2005/06, the river was covered with 0.5-1.0 m thick ice cap, under which numerous soffits with a thickness of up to 3 m accumulated. The resulting jam caused flooding in February 2006. Due to the bathymetry of the river, it was not possible to carry out icebreaking action with the use of icebreakers from the Great Lakes region, therefore the Amphibex equipment was used. The works began on 21st of March and were carried out for 10 days 24 hours a day. In addition, a small tugboat was used to clear the channel below the jam. The progress upstream was slow but stable. On average, the progress of 0.6 km per day was made with 10 days of continuous operation but only 150 metres per day with the trough being cut in the front of the jam.

It is worth comparing the above ice situation and actions taken with the icebreaking action carried out on the Włocławek reservoir during the flooding in the Płock area in 1982. Ice conditions on the reservoir were similar to those observed on the Kaministiquia river, i.e. the ice cover about 0.5 m thick and soffits with a much greater thickness (in some places - above 4 m). The action was initially carried out by 3 icebreakers (Rosomak 500HP, Żubr 500HP and Lemur 408HP), and then two additional units joined (Basior 770HP and Tur 375HP). The works were carried out from 10th of January 1982. During that time the units worked on one shift, extended to tens of hours. The bridge in Płock was reached after 20 days of work, with making a trough with the width of 400 to 200 m. The rate of the icebreakers' work can be estimated at over 2.1 km per day. This gives an idea of the dynamics of the icebreaking action carried out to remove ice jams with use of the Amphibex dredgers and the icebreakers. Taking into account the working time of dredgers (24 hours a day) and icebreakers (working about 12 hours a day), one can say that the efficiency of the icebreakers is more than seven times higher.

## 2 Technical Specification of AMPHIBEX 1200

The 1200 series dredger is the largest model manufactured by Normrock Industries Inc. Its weight is almost six times greater than that of the 400 series (112 tonnes). It is equipped with Caterpilar C32 V-12 diesel engine that produces 1007 kW of power. Despite such a powerful engine, the speed of the dredger on the water is practically the same as that of the smaller model 400, i.e. it does not exceed 8 knots.

Figure 6. Amphibex 1200 dredger; source: [www.normorock.ca](http://www.normorock.ca)

Although the manufacturer emphasises in the information materials that the 1200 model is suitable for the work in the ice, these machines have never been used before for crushing ice. This information was confirmed by a telephone call to the Normrock Industries' Deputy Chairman, Jimmy Grant (13th of September 2018). It means that it is not possible to determine how the Amphibex 1200 will behave when crushing ice or removing jams. For this purpose, tests would be required in conditions similar to those prevailing on the Odra River.

Due to the enormous weight of the Amphibex 1200, it is suspected that it would have difficulty positioning itself in a rapidly flowing water. On the other hand, it can be assumed that the rate of operation of the Amphibex 1200 when crushing the ice cover will be very close to that of the much smaller model 400. The only difference is the width of the trough in the ice, which is likely to be much wider than the width of the runoff channel made by the Amphibex 400. However, two Amphibex 400 devices can be considered, which would guarantee the same parameters of the runoff channel. Due to the larger reach of the excavator arm (15 m), it can be estimated that the 1200 dredger will be more efficient in removing jams. However, due to the lack of field tests, all the above theses are only supported by so-called "expert knowledge" and need to be verified under real conditions with a real machine.

<u>DIMENSIONS:</u>

Length of the operating unit: 18.3 m
Width of the operating unit: 8.53 m
Total weight of the working unit approx. 112 tonnes
Width of the unit during transport on a trailer: 4.3 m
Speed on water: 5 to 8 knots

<u>ENGINE: C9 ACERT CATERPILLAR</u>

12 cylinders
Maximum power: from 1007 kW HP
Fuel tank: 6000 L

<u>EXCAVATOR</u>

Excavation radius: from 15 m at 150°.
Excavation depth (with telescopic indicator): 10.3 m

# 3 Possibility of using Amphibex icebreaking dredgers on the Odra River

The ice phenomena on the Odra River were the subject of several expert opinions, including:

- Kolerski, T., (2017) Verification of the possibility of linear icebreakers' operation in the conditions of the lack of clearing of the central and border Odra river bed (variant 0)
- Kolerski, T., (2014) Protection against jam caused floods on the Lower Odra River and Lake Dąbie
- Project Coordination Office for Flood Protection of the Odra River Basin, Concept document for a new flood protection project, Protection against winter floods (Central Odra and Lower Odra River), Warsaw 2013
- Hydro-Eko, 2004. Summary of flood losses caused by jam caused floods, Poznań

- PROEKO, 2003: The decontamination of the fairway on Lake Dąbie, Feasibility study of the investment,
- Szwalgin D., Zagożdżon J., Feasibility study; Continuation of the icebreaker's construction programme for RZGW Szczecin, VIP Law Firm Ltd. Olsztyn March 2017
- Banasiak R., Garncarz-Wilk B., Selection of sensitive jam caused flood hazard sites on the Odra River from Malczyce water level to the Nysa Łużycka estuary together with estimation of potential flood losses in this section of the river, IMGW Wrocław, October 2015.

All the above studies indicate the commonness and great difficulty in predicting the occurrence of ice jams on the Odra River. Analysing both the border river section and the central Odra River section, it is clear that jams may occur over a large part of the length of the river. The reason for this is both the specificity of the Odra River and many years of negligence with regards to the regulation structures, which have been existing for over 100 years. Moreover, due to the fact that the Odra River flows through the Lake Dąbie in its lower course, the ice cover forms almost every season, expanding from the lake upstream.

The idea of using pontoon excavators for ice breaking on the Odra River is suggested by the German and Polish ecological circles, including Deutsche Naturschützring, WWF, Koalicja Ratujmy Rzeki *[Save the Rivers Coalition]*, Bund für Umwelt und Naturschütz Deutschland, Deutsche Umwelthilfe, Eko Unia, NABU, and others. The reason for the interest of environmental organisations in this technical solution and the proposal to implement it for the Odra River was probably due to the fact that pontoon dredgers could operate on rivers with very small depths or directly on land. An additional advantage, often emphasised by the manufacturer of this solution, is a small impact on the natural environment during the icebreaking operation.

As an alternative to the classic icebreaking actions on the Odra river, which have been used for many years, it requires a detailed comparative analysis. In this report I will focus on the technical aspects in the context of icebreaking and jam neutralisation. A detailed comparison is shown in the table at the end of the study, while the conclusions are presented in the 'Summary' section.

The aim of the project "Flood protection project in the Odra River and Vistula River basins", carried out with the help of international financial institutions, is to improve the flood protection, including winter flood protection under Component 1. One of the basic measures envisaged to ensure the safety of people living in the selected areas of the Odra River basin is the icebreakers construction programme for the RZGW Szczecin. This programme provides for the construction of two linear icebreakers to complement the heavily depleted fleets of icebreakers operating continuously on the lower and central Odra River. The task of the newly designed units is to support the operation of the front icebreakers through continuous monitoring and expansion of the ice runoff channel. This is necessary in order to ensure ice runoff from the front icebreakers' operation area and to prevent formation of jam on the river below. As the simulation carried out in the Kolerski report 2017 has shown, the jam on the border Odra River can form from the inflowing ice in a time of less than one day, reaching the thickness of up to 1m.

The icebreaking on the Odra River is usually carried out over a distance of tens of kilometres up to more than 300 km starting from Lake Dąbie and further upstream. Amphibex is capable to move on the water with the speed of up to 8 knots, and on the ice not faster than 0.5 km/h. This gives a very low rate of progress in the ice, reaching up to 12 km per day at work for 24 hours. Assuming that on the Odra River there will be only an ice cover, it takes about 92 hours for Amphibex to get from the Lake Dąbie to Widuchowa (about 46 km), more than 210 hours to Gozdowice (over 150 km), and more than 300 hours to the estuary of the Warta River (over 150 km). In the case of working for 12 hours a day (in daylight) it will be 8, 18 and more than 25 working days respectively. Of course, this is a very approximate calculation assuming very favourable ice conditions without jams and slush ice soffits. The width of the trough made by the Amphibex machines will depend on the quantity of units used. One unit is able to make a trough with the width of about 5 metres.

Taking into account the rate of development of jams caused by the ice flowing down the Odra River, it must be said with all firmness that the slow and not very dynamic Amphibex dredgers are not able to counteract such phenomena. The only correct solution to neutralise jams is the icebreakers currently in use. Consideration could be given to supplementing the current fleet of icebreakers with one or two Amphibex devices, which could be transported to the place of jam on a trailer and then support the icebreakers working in the jam.

# 4 Summary

On the basis of the above expert opinion, I draw the following conclusions.

1. The Amphibex equipment can be used for icebreaking but this process is expensive and inefficient. These units are designed for streams and small rivers of low depth, where it is not possible to use other technical means to break the ice. The largest river on which this ice crushing solution is successfully used is the Red River in the province of Manitoba with an average flow in the mouth of 244 $m^3/s$ (the Odra flow at estuary is 535 $m^3/s$).
2. With very low efficiency, the use of the Amphibex dredgers on the border Odra River would result in the need to start the icebreaking action many days before the anticipated ice run. According to the estimated calculations, clearing the section between Lake Dąbie and Widuchowa (approx. 46 km) will require more than a week of work on a 12-hour shift. With an expensive and highly engaging icebreaking action, one has to rely on certain weather forecasts, and such long-term forecasts do not ensure a high verifiability.
3. Amphibex dredgers cannot replace linear icebreakers. The tasks to be carried out by the linear icebreakers planned to be built are not compatible with the functions of the Amphibex dredgers. These machines are not able to move quickly along the river to monitor the ice runoff and using them to widen the runoff channel is very slow and inefficient.
4. The Amphibex units can be helpful in neutralising jams, but their capacity is well below that of classic icebreakers. In some situations, a slow but systematic operation of excavators can help icebreakers remove ice jams but absolutely cannot replace them on the Odra River.
5. Amphibex can also carry out the front icebreaker's work by preparing a runoff channel for the ice. In this case, the comparison with the front icebreakers is very much in the advantage of the latter. The rate of the icebreakers' work is almost 20 times faster than that of dredgers. The only justification may be an ice cover more than 0.5 m thick but such cases do not occur on the Odra

River. Using more units does not increase the speed of work but only results in making a wider trough in the ice cover or jam. The use of Amphibex dredgers in the crushing of the ice cover can complement but not replace the work of classic front icebreakers on the Odra.

The table below summarises the applicability of the Amphibex 400 dredgers in different ice situations, compared to classic icebreakers as well as the Amphibex 1200 dredger.

Table 1. Comparison of the Amphibex 400, Amphibex 1200 and classic icebreaker (both the designed LL-402 linear icebreaker and the new front units are listed)

| | Amphibex 400 | Amphibex 1200 | Icebreakers |
|---|---|---|---|
| Preventive action to prepare the river before the ice run. | YES | YES, but not used so far | YES (front icebreakers) |
| Linear operation for widening the runoff channel | YES – very slow operation | YES, but not used so far | YES (linear icebreakers) |
| Monitoring of the ice runoff channel | NO | NO | YES (linear icebreakers) |
| Speed on water | 5 – 8 knots | 5 – 8 knots | Depending on model |
| Work rate for crushing the ice cover | appr. 0.2 ha/hour | No data available, not used yet | Appr. 3 ha/hour |
| Progress in the execution of an ice trough | Not more than 0.5 km/hour | No data available, not used yet | Approximately 6 km/hour (estimated number to be consulted with icebreakers crews) |
| Ice thickness | Up to 0.75 cm | Above 1.0 m (high weight – 112 tonnes) | Up to 0.5 m |
| Trough width | Appr. 5 m with one Amphibex 400 | Appr. 15 m (estimated on the basis of dimensions) | Appr. 20 m when using a single icebreaker. |
| Cost of operation[1] | 1770 USD/ha | Not known | 1003 USD/ha |
| Removal of ice jams | YES | YES, but not used so far | YES (front icebreakers) |
| Speed of work in jam | 25 m/hour on average<br>Jam front 8 m/hour[2] | No data available, not used yet | Average 180 m per hour<br>Jam front: not more than 80 m/hour[3] |
| Required minimum depth | No requirements | No requirements | 1.8 m for high power icebreakers (for LL-402 class line icebreakers)<br>1.0 m for small auxiliary units (e.g. LR-400 Delfin) |
| Power | From 200 up to 275 kW | 1007 kW | 588 kW (LL-402 icebreaker)<br>785 kW (Andrzej front icebreaker)<br>1176 kW (Stanislaw front icebreaker) |
| Cost of the unit | Approximately 1.2 million Canadian dollars = PLN 3.4 million | PLN 20,4 million | Approximately PLN 20 million |

[1] According to CREEL Report, Haehnel, Robert B. 1998 "Non-structural ice control". COLD REGIONS RESEARCH AND ENGINEERING LAB HANOVER NH

[2] Calculated on the basis the icebreaking operation on the Kaministiquia River in the Province of Ontario

[3] Calculated on the basis of the icebreaking action on the Włocławek reservoir in February 1982.