TRANSPORT
2010
25(2): 178–185

A PROPOSAL FOR THE MODELS AND MEASURES OF SEARCH AND RESCUE ON INLAND WATERWAYS

Pero Vidan[1], Josip Kasum[2], Natalija Jolić[3]

[1]*University of Split, Maritime Science Academy, Zrinsko Frankopanska 38, 21000 Split, Croatia*
[2]*Croatian Hydrographic Institute, Zrinsko Frankopanska, 21000 Split, Croatia*
[3]*Faculty of Traffic Sciences, Vukelićeva 4, 10000 Zagreb, Croatia*
E-mails: [1]pvidan@pfst.hr; [2]jkasum@hhi.hr; [3]natalija@fpz.hr

Received 1 September 2009; accepted 20 May 2010

Abstract. Search and rescue on inland waterways are considered to be insufficiently developed. The methods of search and rescue have been developed only for sea waterways. Despite the possibilities of comparison, the specific characteristics of inland waterways are the reason why it is seriously considered to develop proposals for search and rescue models on inland waterways. The authors of this paper suggest a search and rescue model for rivers, lakes and channels regarding configuration and the current safety conditions on inland waterways. The model allows a successful quest for reduced search time. In addition, the model predicts the performance of the search.

Keywords: search, rescue, search model, inland waterways, measures, safety.

1. Introduction

Inland waterways are understood as navigationally passable waterways of rivers, lakes and channels organized, marked and open to safe navigation (Dadić *et al.* 1996; Rohács and Simongáti 2007; Ivakovic *et al*. 2008; Brnjac and Cavar 2009; Camp *et al*. 2010). Search and rescue services on inland waterways are considered as poorly developed. According to Jolić (2005) and and Vojković (2007), one of the reasons lies in the long predominance of sea traffic over traffic on inland waterways. Science and profession describe in detail search and rescue methods at sea where search and rescue operations are regulated by the *International Maritime Organization – IMO* (Zec 2001) that is obligatory and implemented in practice.

Inland waterways are being increasingly exploited. The reason lies in the economic cost-efficiency of traffic on inland waterways compared to other types of land transport (Communication from the Commission … 2006; Brnjac and Cavar 2009). However, safety on inland waterways is not developing at the same speed. Thus, for instance, on inland waterways, search methods have not been sufficiently studied (Contesting it Sustainability … 2005).

Ships at sea are equipped with rescue means, including life jackets, lifebuoys, rafts, lifeboats, EPIRB (*Emergency Positioning Indication Radio Beacon – EPIRB,* COSPAS – SARSAT), SART (*Search and Rescue Transponder – SART*), pyrotechnic devices, etc. A part of this equipment is also used for search and rescue operations on inland waterways. Lifeboats and life-rafts are equipped with life-saving appliances. It is of great importance for ship crew members to get familiar with the means and equipment for rescue activities that can be found onboard their ships.

The Convention for the Safety of Life at Sea (*SOLAS*) regulates the obligation of ship crew members to be familiar with life-saving appliances and equipment which means independent handling, knowing equipment properties, a position of life-saving appliances onboard and means inventory (Zec 2001).

Ship crew members acquire a working knowledge of the basics of search and rescue operations through special courses stipulated by the *International Convention on Standards of Training Certification and Watchkeeping – STCW* 1978/1995. STCW Convention defines search and rescue training.

The concept of the search defines locating the position of people in distress which means that life or craft is in imminent danger. It may result in loss of human lives, injury to people, loss or damage of a ship, cargo and objects around the ship. According to SAR Seamanship Reference Manual (2000), rescue is considered successful if human lives are saved.

Rescue is considered even more successful if a ship is saved along with cargo. In general, rescue is consid-

ISSN 1648-4142 print / ISSN 1648-3480 online
www.transport.vgtu.lt
doi: 10.3846/transport.2010.22

ered to be more successful if search time has been reduced to a minimum. Finding people and goods within the shortest time increases the possibility of survival with ship and goods not permanently lost.

2. Search on Inland Waterways

The search on inland waterways should be adapted to the configuration of inland waterways and temporary safety conditions on the waterway. Safety conditions on the inland waterway include:

- waterway confinement;
- influence of water currents;
- water level;
- weather conditions;
- other factors.

The confinement of the waterway results from the size of that. The dimensions of the waterway are defined by the width, depth and height of the passage on the inland waterway (Čolić *et al.* 2005). The waterline depends on the indentation and curves of the waterway. The curvature and indentation of the waterway directly affect the visibility of the waterway.

Water currents on inland waterways are considered as significant factors that make rescuing more difficult, particularly in the period of extreme precipitations. During the search, the direction and force of water currents need to be taken into consideration. The force of the current depends on water flow supply. The current direction is determined by water flow unless the river or lakes have burst its banks.

Water level is the measure of water height for a certain area. Water level is proportional to water currents (Pomorski leksikon 1990).

Weather conditions affect the method and results of search and rescue operations. Unfavourable weather conditions include:

- reduced visibility;
- precipitations;
- occurrence of ice;
- reduced air and water temperatures.

Low temperatures may result from the influence of air or water. The feeling of coldness increases with increased wind (Table 1), see National Search and Rescue Manual (2006). Inland waterways are considered colder than those at sea. During winters, ice often occurs on many inland waterways. The threat for endangered people lies in the immediate contact with water. The danger of drowning due to the weather phenomena is high and may significantly affect search and rescue duration.

Other factors are rare, have less influence on the search results and therefore are not mentioned in this paper.

The exposure of the human organism to low temperatures causes *hypothermia* which is the fall of body temperature due to exposure to low temperatures. If the human organism is exposed to low temperatures for a longer period of time, death may be the result (Fig. 1, Table 2) (National Search and Rescue Manual 2006).

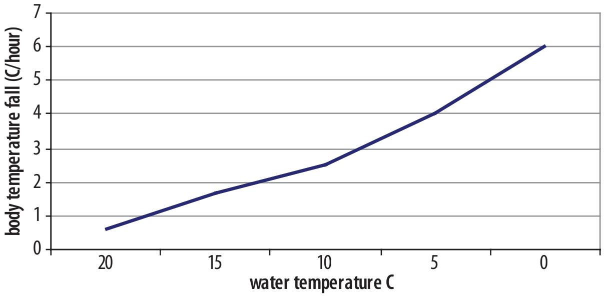

Fig. 1. The graph of the rate of body temperature fall for a lightly dressed person who does not move through water and wears a life jacket (National Search and Rescue Manual 2006)

Table 1. Influence of wind on the perceived temperature (National Search and Rescue Manual 2006)

Wind speed (m/s)	Air temperature (°C)						
	–10	–5	0	5	10	15	20
5.0	–20.7	–14.5	–8.2	–2.0	4.3	10.5	16.8
7.5	–25.6	–18.8	–12.0	–5.1	1.7	8.5	15.3
10	–28.9	–21.7	–14.5	–7.3	–0.1	7.1	14.3
12.5	–31.2	–23.8	–16.3	–8.8	–1.4	6.1	13.6
15.0	–32.9	–25.2	–17.6	–9.9	–2.2	5.4	13.1
17.5	–34.0	–26.2	–18.4	–10.6	–2.9	4.9	12.7
20.0	–34.7	–26.9	–19.0	–11.1	–3.2	4.6	12.5
22.5	–35.1	–27.2	–19.3	–11.4	–3.4	4.5	12.4
25.0	–35.2	–27.3	–19.3	–11.4	–3.5	4.5	12.4
27.5	–35.0	–27.1	–19.2	–11.3	–3.4	4.5	12.4
30.0	–34.7	–26.8	–18.9	–11.1	–3.2	4.7	12.5
32.5	–34.1	–26.3	–18.5	–10.7	–2.9	4.9	12.7
35.0	–33.4	–25.7	–18.0	–10.3	–2.5	5.2	12.9

Table 2. Approximate time of death before fainting i. e. the death of a person of the average constitution (National Search and Rescue Manual 2006)

Sea temperature (°C)	Fainting	Death
0	15 min	0.25–1.5 hours
10	0.5–1 hours	1–2 hours
15	2–4 hours	6–8 hours
20	3–7 hours	20–30 hours
25	12 hours	more than 30 hours

The recommendation is searching by ship on river upstream. This procedure shortens time necessary to arrive to the search target since it moves towards searching means carried by the water current. The suggestion is to categorize waterways according to their *search width*. Considering such categorization, waterways may be:

- narrow for searching;
- wide for searching.

The search for narrow waterways includes all waterways with both left and right bank lines clearly visible from the midstream under the current meteorological conditions.

The search for wide waterways is considered to be all waterways with both left and right bank lines not clearly visible from the midstream under the current meteorological conditions.

The current meteorological conditions are the current visibility, waves, wind, precipitations and other factors. This leads to the conclusion that the width of the waterway is a changeable variable for search and rescue and these operations will have to be adjusted to it.

Searching for narrow waterways should be parallel to the bank line, particularly in cases it is a narrower waterway and the search is performed by a single ship. It is suggested to start the search at a reference point which should be the point of the probable position of the searched object. The reference point for rivers can be calculated according to the relation:

$$D = B_{r(\max)} \cdot t \text{ [km]}, \quad (1)$$

where: D – distance in km from the last known place of distress (the distance is calculated in the downstream direction, i. e. the direction in which the water flows); $B_{r(\max)}$ – the maximum speed of the river current; t – a period of time from distress.

If the search is performed by several ships on a wide river waterway, it is recommended upstream and parallel with the bank line (Fig. 2). A wide waterway for searching is considered the waterway with bank lines that are not clearly visible from the midstream under the current meteorological conditions during search and rescue operations. The reference point should be calculated according to formula (1). The search should be carried out by forming several search sweeps the width of which should depend on the visibility and size of the searched object. The number of sweeps N_s equals the number of course changes that is proportional to the searched waterway area and search route width:

$$N_s = \frac{P_{pl}}{P_{st}}, \quad (2)$$

where: P_{pl} – the searched waterway area; P_{st} – search route area.

The search conducted by a single ship on a wide river waterway should be upstream in zigzag courses (Fig. 3). For this type of searching, a ship of favourable manoeuvring characteristics and appropriate dimensions for waterway width is required.

The search in zigzag courses is suitable since there is less possibility of carrying the object downstream during the search on one side of the waterway. The number of course changes n_k on a certain area in zigzag search from relation is calculated according to relation (2).

Since the waterway is defined by the radius of curvature (Fig. 4), one may say that the waterway area of

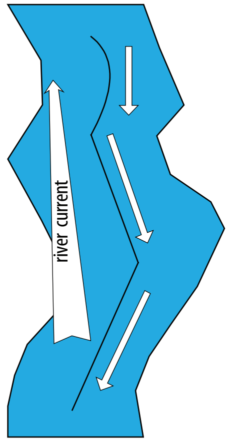

Fig. 2. Search by a single ship on the river upstream

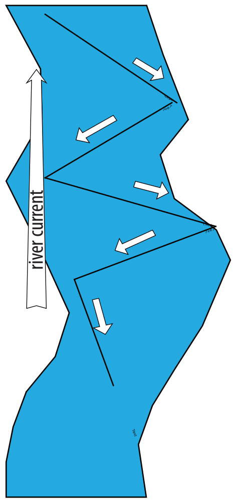

Fig. 3. Search in zigzag on the river upstream

segment P_{pl} is approximately equal to difference in the areas of two circular sectors of concentric circles:

$$P_{pl} = \frac{r \cdot l}{2} \text{ [km}^2\text{]}, \quad (3)$$

where: l – the length of the bank line of the larger circular sector of the river curve; r – the curvature radius of the smaller circular sector of the river curve or

$$P_{pl} = r^2 \cdot \pi \cdot \frac{\beta}{360°} \text{ [km}^2\text{]}, \quad (4)$$

where: β – the angle of the circle sector within the river curve; r – the radius of the curvature of the river curve.

$$P_{pl} = P_{pl} - P_{pl2} \text{ [km}^2\text{]}; \quad (5)$$

$$P_{pl} = \frac{r_1 \cdot l_1 - r_2 \cdot l_2}{2} \text{ [km}^2\text{]}, \quad (6)$$

where: r_1 – the radius of the curvature of the larger section; r_2 – the radius of the curvature of the smaller section,

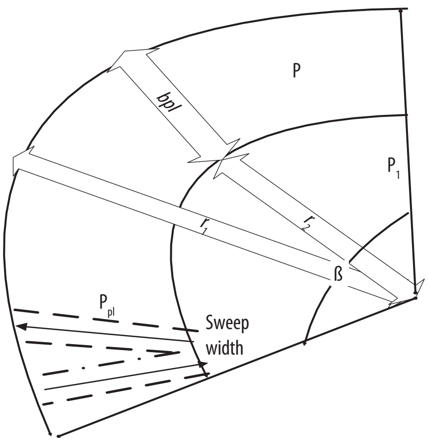

Fig. 4. Values to calculate the number of sweeps

that is:

$$P_{pl} = \frac{\beta \cdot \pi \cdot (r_1 - r_2)}{360°} \ [\text{km}^2]. \quad (7)$$

If (7) inserted into relation (2):

$$N_s = \frac{\beta \cdot \pi \cdot (r_1 - r_2)}{P_s \cdot 360°}. \quad (8).$$

The above mentioned formula yields to the acceptable results of the river curves. For the straight river section (Fig. 5), the number of sweeps N_s, is calculated as:

$$N_s = \frac{P_{pl2}}{P_s}; \quad (9)$$

$$P_{pl2} = b_{pl} \cdot D_{pl} \quad [\text{km}^2]; \quad (10)$$

$$N_s = \frac{b_{pl} \cdot D_{pl}}{P_s}, \quad (11)$$

where: D_{pl} – the length of the waterway searching area.

$$P_{pl2} = \sum_{i=1}^{n} P_{pl\,n} \quad [\text{km}^2]. \quad (12)$$

If inserted into formula (9):

$$N_s = \frac{P_{pl2}}{P_s} \Rightarrow N_s = \frac{\sum_{i=1}^{n} P_{pl\,n}}{P_s}. \quad (13)$$

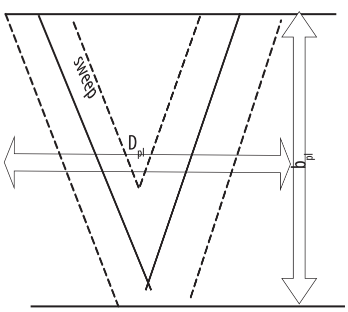

Fig. 5. Parameters for the straight river section

The inland waterway can be presented functionally (Fig. 6).

If $f_1(x)$ is the left bank line and $f_2(x)$ is the right bank line, then the area between them equals the difference of areas on segment (x_1, x_2), i. e.:

$$P_j = f_1(x) \cap f_2(x); \quad (14)$$

$$P_{pl} = \left(\int_{x_1}^{x_2} f_1(x)dx - \int_{x_1}^{x_2} f_2(x)dx \right) \ [\text{km}^2]; \quad (15)$$

$$P_{pl} = \int_{x_1}^{x_2} (f_1 - f_2)dx \ [\text{km}^2]. \quad (16)$$

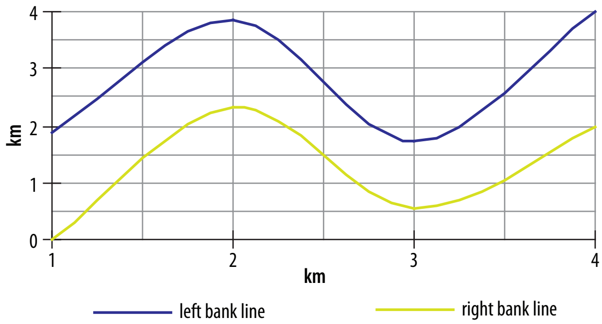

Fig. 6. A functional presentation of the left and right bank lines

If inserted into formula (2):

$$N_s = \frac{\int_{x_1}^{x_2} (f_1 - f_2)dx}{P_s}. \quad (17).$$

The number of routes is the estimate of *on scene commander (OSC)* that is suggested to be the master of the public service vessel in charge of search and rescue operations. Such a vessel may belong to the river coastguard, police, army, Harbour Master's Office, etc. (Zec 2001). The number of sweeps should depend on the area of waterway segment P_{pl}, search range (depends on visibility V_{isb} and waterway curvature radius R), the size of the searched object M, the height of observer h and other factors ost. Generally, it should be expressed as follows:

$$N_s = f\left(P_{pl}, V_{isb}, R, M, h, ost\right); \quad (18)$$

$$P_s = f\left(V_{isb}, R, M, h, ost\right). \quad (19)$$

The duration of search t_t is calculated according to the formula:

$$t_t = \frac{N_{os}}{v_b} \ [\text{h}], \quad (20)$$

where: N_{os} – the number of sweeps determined by the on scene commander; v_b – the speed of a search and rescue ship.

Formula (20) is valid only for the search using a single ship. If the search is performed involving several ships n_b, then the following formula is valid:

$$t_t = \frac{N_{os}}{v_b} \cdot \frac{1}{n_b} \text{ [h]}. \quad (21)$$

Search time depends directly on the success of the search:

$$t_t = f\left(uspt\right) \text{ [h]}. \quad (22)$$

Search success is the probability of the positive search result the probability of which is defined as a function of the probability of finding the searched object. It may have the value of interval (0, 1) and may be designated as K (Frost 1999):

$$K = \frac{POC}{A}, \quad (23)$$

where: POC – the probability that the searched object is contained in the search area *(Probability of Containment – POC)*; A – the search zone area.

If inserted into relation (21):

$$t_t = \frac{N_{os}}{v_b} \cdot \frac{1}{n_b} \cdot \frac{1}{K}, \quad K = (0, 1). \quad (24)$$

On lakes, sea searching methods should be applied since there are no extreme water currents. These are methods for Expanded Square Search and Sector Search such as implemented in the sea search (Fig. 7) (Bowditch 2010).

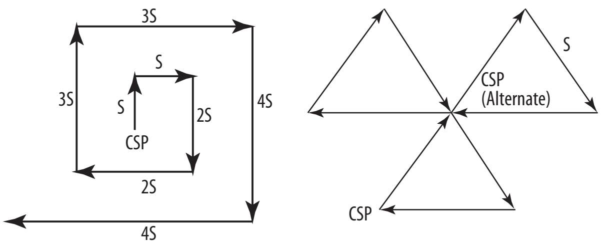

Fig. 7. The search using the methods of Expanded Square Search and Sector Search

The length of navigation on a certain course, S, depends on the size of the searched object M, the height of observer h, visibility V_{isb}, surface condition s_{tp} (waves) and other factors ost.

$$S = f\left(V_{isb}, M, h, s_{tp}, ost\right). \quad (25)$$

In exploring the search area on lake inland waterways, it is possible to define the *Search Area*. The *Possible Search Area* is described as the minimum area in which it is certain that there are people in distress. This area usually has large dimensions, and therefore it is considered necessary to be divided into smaller areas (Frost 1999) (Fig. 8). Each smaller area is assigned the value of the probability of finding the search target POC. According to Frost (1999), POC can be determined for the simplest case according to the expression:

$$POC = 1 - e^{\frac{R^2}{2}}, \quad (26)$$

where: R – total navigation error.

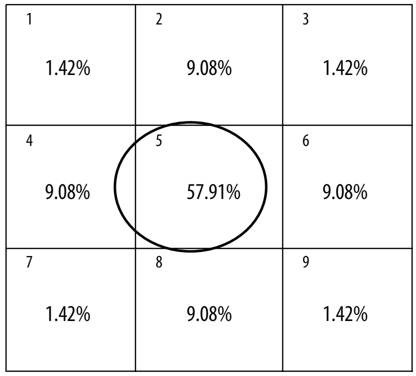

Fig. 8. The probability of the Containment of the search target according to sectors (Frost 1999)

It is considered that a single or several points can have the same *Probability of Containment*. The most probable position of the search target can be determined as:

– geographical point;
– line;
– area.

The geographical point is designated as the highest *Probability of Containment* based on the collected data. All other points in the neighbourhood have a relatively lower *Probability of Containment.* The line or several lines are composed of the points of approximately the same *Probability of Containment*. An area is determined when it is impossible to determine a point or line as a part of the plane with the points of approximately the same probability (Zec 2001).

If the lake is described functionally (Fig. 9), one may say that the northern lake bank is function f_2 and the southern one – f_1. The area of the lake will be a cross-section of these two functions:

$$P_j = f_1(x) \cap f_2(x). \quad (27)$$

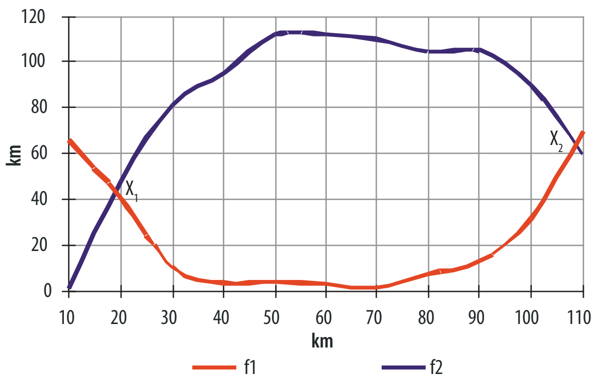

Fig. 9. Presenting the bank lines of lake functionally

f_1 and f_2 functions intersect at points x_1 and x_2. The area of the lake described by the functions between the intersection points will be:

$$P_j = \left(\int_{x_1}^{x_2} f_1(x)dx - \int_{x_1}^{x_2} f_2(x)dx \right) \text{ [km}^2\text{]}; \quad (28)$$

$$P_j = \int_{x_1}^{x_2} \left(f_1 - f_2 \right) dx \text{ [km}^2\text{]}. \quad (29)$$

The number of sweeps in ship search will be:

$$N_s = \frac{P_j}{P_s};$$

$$N_s = \frac{\int_{x1}^{x_2} \left(f_1 - f_2 \right) dx}{P_s}.$$

The sweep is described by its length s and width a and has a form of an elongated rectangle. The area of route P_s is:

$$P_s = a \cdot S \text{ [km}^2\text{]}. \quad (30)$$

Width between sweeps a depends on the current conditions on water (Table 4). The length of sweep S is the sum of sweeps s which forms the mathematical series:

$$S = s_0 + 2 \cdot n \cdot s_1 + 2 \cdot (n+1) \cdot s_1 + 2 \cdot (n+2) \cdot s_1 + \ldots . \quad (31)$$

It follows that the partial sums of the given mathematical series are as follows:

$$S_1 = s_0 + 2 \cdot n \cdot s_1 .$$

$$S_2 = s_0 + 2 \cdot n \cdot s_1 + 2 \cdot (n+1) \cdot s_1 ;$$
$$S_2 = s_0 + 2 \cdot s_1 \cdot (n+n+1);$$
$$S_2 = s_0 + 2 \cdot s_1 \cdot (2 \cdot n+1);$$
$$S_2 = s_0 + 2 \cdot n \cdot s_1 + 2 \cdot (n+1) \cdot s_1 ;$$
$$S_2 = s_0 + 2 \cdot n \cdot s_1 + 2 \cdot (n+1) \cdot s_1 ;$$
$$S_2 = s_0 + 2 \cdot s_1 \cdot (n+n+1);$$
$$S_2 = s_0 + 2 \cdot s_1 \cdot (2 \cdot n+1) .$$

$$S_3 = s_0 + 2 \cdot n \cdot s_1 + 2 \cdot (n+1) \cdot s_1 + 2 \cdot (n+2) \cdot s_1 ;$$
$$S_3 = S_2 + 2 \cdot (n+2) \cdot s_1 ;$$
$$S_3 = s_0 + 2 \cdot s_1 \cdot (2 \cdot n+1) + 2 \cdot s_1 \cdot (n+2) ;$$
$$S_3 = s_0 + 2 \cdot s_1 \cdot (2 \cdot n+1+n+2) ;$$
$$S_3 = s_0 + 2 \cdot s_1 \cdot (3 \cdot n+3) .$$

$$S_4 = s_0 + 2 \cdot n \cdot s_1 + 2 \cdot (n+1) \cdot s_1 + 2 \cdot (n+2) \cdot s_1 + 2 \cdot (n+3) \cdot s_1 ;$$
$$S_4 = S_3 + 2 \cdot (n+3) \cdot s_1 ;$$
$$S_4 = s_0 + 2 \cdot s_1 \cdot (3 \cdot n+3) + 2 \cdot s_1 \cdot (n+3) ;$$
$$S_4 = s_0 + 2 \cdot s_1 \cdot (n+3+n+3) ;$$
$$S_4 = s_0 + 2 \cdot s_1 \cdot (4 \cdot n+6) .$$

…………

$$S_k = s_0 + 2 \cdot n \cdot s_1 + 2 \cdot (n+1) \cdot s_1 + 2 \cdot (n+2) \cdot s_1 + 2 \cdot (n+3) \cdot s_1 + \ldots + 2 \cdot (n+(k-1)) \cdot s_1 ;$$

$$S_k = s_0 + 2 \cdot s_1 \times (n+1+n+2+n+3+\ldots+n+(k-1));$$

$$S_k = s_0 + 2 \cdot s_1 \times \left(\left(\underbrace{n+n+\ldots.+n}_{k \text{ times}} \right) + \left(0+1+2+3+\ldots+(k-1) \right) \right);$$

$$S_k = s_0 + 2 \cdot s_1 \left(k \cdot n + \frac{(0+(k-1)) \cdot k}{2} \right);$$

$$S_k = s_0 + 2 \cdot s_1 \left(k \cdot n + \frac{k-1}{2} k \right).$$

Since $S = \lim_{k \to \infty} S_k$, it follows that:

$S = s_0 + 2 s_1 \lim_{k \to \infty} \left(k \cdot n + \frac{k-1}{2} k \right)$, the mathematical series diverges.

Since this refers to a finite order, i. e. $k \to N$, then

$$S = s_0 + 2 \cdot s_1 \lim_{k \to N} \left(k \cdot n + \frac{k-1}{2} k \right);$$

$$S = s_0 + 2 \cdot s_1 \left(N \cdot n + \frac{N-1}{2} N \right).$$

If inserted into formula (28),

$$P_s = a \cdot s \text{ [km}^2\text{]};$$

$$P_s = a \cdot \left(s_0 + 2 \cdot s_1 \lim_{k \to N} \left(k \cdot n + \frac{k-1}{2} k \right) \right);$$

$$P_s = s_0 + 2 \cdot s_1 \left(N \cdot n + \frac{N-1}{2} N \right) \text{ [km}^2\text{]}. \quad (32)$$

Table 3. The size of the gap between sweep (s) for commercial ships and rescue units (Zec 2001)

Target	Meteorological visibility (km)				
	5.5	9	18.5	28	37
Person in the water	0.7	9	1	1.3	1.3
Raft (4 persons)	4.3	6	7.8	9	10
Raft (6 persons)	4.6	6.7	9.3	11.5	12.8
Raft (15 persons)	4.8	7.4	9.4	11.9	12.8
Raft (25 persons)	5	7.8	9.6	12	13.9
Lifeboat <5m	2	2.6	3.5	3.9	4.3
Lifeboat 7m	3.7	5.4	8	9.6	10.8
Lifeboat 12m	5.2	8.3	14.1	17.4	21.5
Lifeboat 24m	5.9	10.4	19.8	27.2	33.5

Search and rescue operations on lakes can be difficult due to meteorological hydrological conditions on water (Table 3 and 5). For example, such difficulties may include strong wind, waves and strong currents. In cases of strong wind and currents, there may be certain drift

(Kotsch 1984). The drift of the search target depends on the displacement of the search target, the size of the freeboard of the search target, etc. (Ljubetić 1989). The intensity of drift is presented in Table 4.

Table 4. Vessel drift (except rafts) under the influence of wind (Zec 2001)

Type of vessel	Drift (% of wind speed)
windsurfing board	2%
heavier ships of deeper draught	3%
mid-heavy ships, fishing ships	4%
Bigger ships	5%
Smaller ships	6%

Table 5. Drift due to the sea current and wind (Zec 2001)

Wind force (Bf)	Wind speed (kn)	Sea current speed (M/day)
1	1–3	2
2	4–6	4
3	7–10	7
4	11–16	11
5	17–21	16
6	22–27	21
7	28–33	26

Program packages should be developed to provide the *on scene commander* with the calculation of search time, the number of sweeps, search probability, etc. This would help the *on scene commander* in making decisions on the method of search coordination and in reducing the possible human errors and oversights. The program packages for computers should be developed according to a general algorithm presented in Fig. 10.

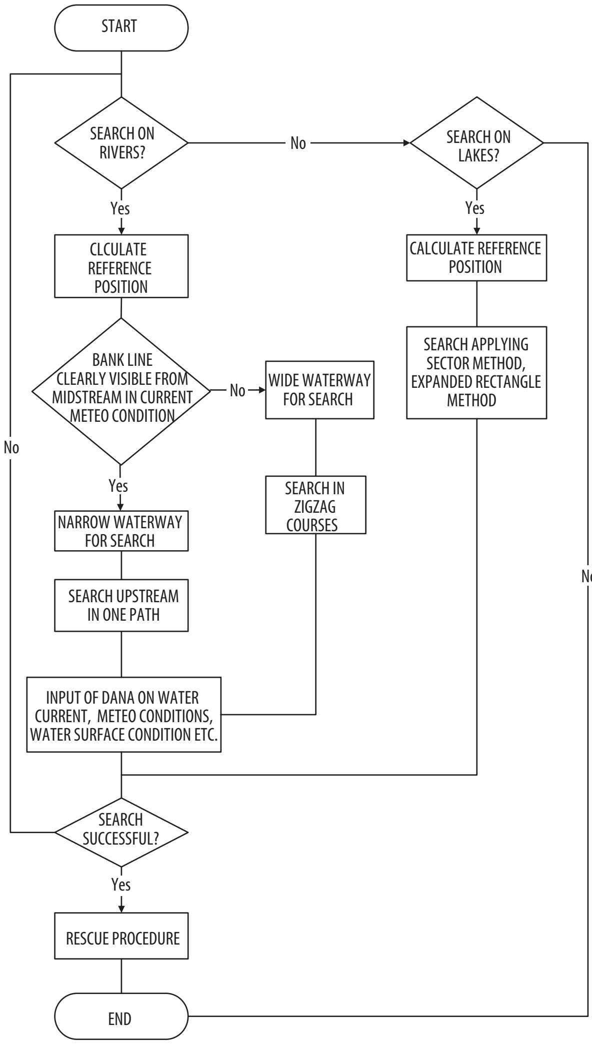

Fig. 10. General search algorithm for the rescue of a drowning person on inland waterways

3. Conclusions

The theory of the search on inland waterways is considered to be insufficiently developed in comparison to the theory of the search at sea. A partial reason of underdevelopment can be accepted to be the insufficient usage of inland waterways compared to those of the sea.

Traffic on inland waterways has increased in the recent years since this branch of land traffic has been recognized as the least expensive one for transport. Infrastructure, suprastructure, traffic management organizations, inspection services and search and rescue organizations are thought to have failed to follow traffic development on waterways.

The International Maritime Organization should urgently elaborate the implementation of an adequate theory of search and rescue services on inland waterways and define the minimal equipment. At the moment, for instance in the Republic of Croatia, regulations on traffic, search and rescue, etc. rely on the Maritime Law. Such a solution is considered as insufficient due to the specific characteristics of navigation on inland waterways.

Computer programs should be developed according to the proposals given in this paper in order to improve search and rescue services on inland waterways. It is justified to expect the programs to make it easier for river coastguard and on scene commanders to organize search and rescue operations. A better organization of search and rescue operations would contribute to greater success in the protection of human lives and assets and would greatly increase the safety of navigation on inland waterways.

References

Bowditch, N. 2010. *The American Practical Navigator*. Paradise Cay Publications. 896 p.

Brnjac, N.; Cavar, I. 2009. Example of positioning intermodal terminals on inland waterways, *Promet Traffic & Transportation* 21(6): 443–449.

Camp, J. S.; LeBoeuf, E. J.; Abkowitz, M. D. 2010. Application of an enhanced spill management information system to inland waterways, *Journal of Hazardous Materials* 175(1–3): 583–592. doi:10.1016/j.jhazmat.2009.10.045

Communication from the Commission on the Promotion of Inland Waterway Transport 'NAIADES': An Integrated European Action Programme for Inland Waterway Transport. 2006. Brussels: Commission of the European Communities. 44 p. Available from Internet: <http://ec.europa.eu/transport/iw/doc/2006_01_17_naiades_staff_working_en.pdf>.

Contesting it Sustainability from a Communication Perspective. 2005. Denmark: Institute for History, International Social Studies Aalborg University. Available from Internet: <http://www.gds.ihis.aau.dk/GetAsset.action?contentId=3426698&assetId=3427110>.

Čolić, V.; Radmilović, Z.; Škiljaica, V. 2005. *Vodni saobraćaj* [Water Transport]. Beograd: University of Belgrade. 27 p. (in Serbian).

Dadić, I.; Smolić, L.; Đaković, N. 1996. *Organizacija i eksploatacija riječnog prometa* [Organization and Exploitation of River Transport]. Zagreb: University of Zagreb. 34 p. (in Croatian).

Frost, R. 1999. *Principles of Search Theory*. Virginia: Soza & Company Ltd. Part III. Available from Internet: <www.sarinfo.bc.ca/Library/Planning/PrincSrchThry_S.pdf>.

Ivakovic, C.; Rogic, K.; Protega, A. O. 2008. Traffic on the croatian inland waterways in the context of the european programme NAIADES, *Promet Traffic & Transportation* 20(6): 383–393.

Jolić, N. 2005. Luke i ITS [Ports and ITS]. Zagreb: University of Zagreb, Faculty of Traffic Science. 117 p. (in Croatian).

Kotsch, W.; Henderson, R. 1984. *Heavy Weather Guide*. US Naval Institute Press; 2 sub-edition. 399 p.

Ljubetić, M. 1989. *Otpor i propulzija broda* [Ship Resistance and Propulsion]. Dubrovnik: Faculty of Maritime Studies. 17 p. (in Croatian).

National Search and Rescue Manual. 2006. Canberra: AMSA, Australian National Search and Rescue Council. 234 p. Available from Internet: <http://natsar.amsa.gov.au/Manuals/Search_and_Rescue_Manual/Combined_SAR_Manual.pdf>.

Pomorski leksikon. 1990. [Maritime Lexicon]. Zagreb: Jugoslavenski leksikografski zavod "Miroslav Krleža". 915 p. (in Croatian).

Rohács, J.; Simongáti, G. 2007. The role of inland waterway navigation in a sustainable transport system, *Transport* 22(3): 148–153.

SAR Seamanship Reference Manual. 2000. Ottawa, Canada. Search and Rescue, Canadian Coast Guard. 468 p. Available from Internet: <www.ccg-gcc.gc.ca/folios/00027/docs/SAR_Manual-eng.pdf>.

Vojković, G. 2007. *Luke unutarnjih voda* [Inland Waterways Ports]. Split: Croatian Hydrographic Institute. 26 p. (in Croatian).

Zec, D. 2001. *Sigurnost na moru* [Safety at Sea]. Rijeka: Faculty of Maritime Studies (in Croatian).