

Comprehensive Methods of the Minimum Safe Under Keel Clearance Valuation to the Restricted Tidal Waters

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ABSTRACT: The main purpose of the paper is familiarization with the matter of most crucial aspects of the minimum under keel reserve for the sea-going ships navigating on the restricted tidal waters. For the purpose of this paper, river Humber was used as good example of high tidal range in conjunction with variety weather conditions encountering in this area affecting the tides. The Author made use of his research and job experience as the pilot, closely co-operating with other authorities, e.g. Vessel Traffic Service (VTS) Humber, local Hydrographic Department as well as Maritime Coastguard Agency (MCA) and Maritime Accident Investigation Bureau (MAIB). The extensive statistics of groundings and near miss situations, in connection with in-depth analysis will be due to presented with conclusions and proposals of sorting out some problems. The new concept of Dynamic Under Keel Clearance DUKC® software with the trials assessments will be widely put forward in compare with currently utilizing tools and software by VTS and Ships' Traffic Centre.

1 INTRODUCTION

1.1 *Criteria of the subject choice*

It is a common knowledge that statistical, groundings are on the top of the list of all reported ships' accidents, incidents and near miss situations. Upon UK Maritime Accident Investigation Bureau (MAIB) reports, groundings represented 73.2% of all noted ships accidents last year and over 64% for the latest decade. Additionally, groundings are in strict conjunction with secondary hazards and accidents, appearing shortly after that, e.g. oil pollution, lost of the stability, damage to the hull and finally collision with other ships in extreme cases. The above mentioned hazards classified in conjunction with the groundings represent 7.5% of the total number listed accidents. Significant numbers (over 55% roughly – precise estimations are still under the count) of all groundings had happened on the restricted waters, such as rivers, estuaries, bays and creeks. The average tidal range for these cases was above 5 meters.

Due to the careful study and analysis, it was concluded that the main reasons of the majority of the total groundings were insufficient under keel clearance, errors in squat assumption and wrongly calculated tidal figures in connection to the passage plans.

The groundings are relatively easy to classify, so any precautionary measures should be selected very

carefully using all available traditional methods with modern software and sophisticated tools.

1.2 *River Humber as an example of restricted tidal area*

The Humber Estuary is one of the busiest trade routes in Britain and represents about 11% of overall seaborne trade.

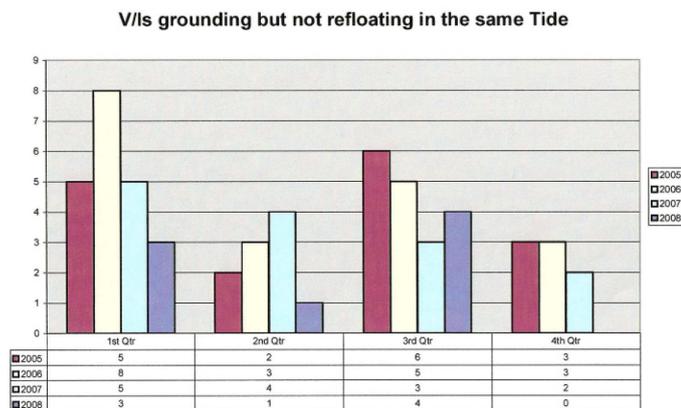
Numerous sandbanks, swift tidal currents, dense traffic, dynamic changing of bathymetric data and unprecedented elsewhere siltation, do the River Humber very difficult for navigation and conservancy. Since 1972 the VTS Humber likely others in Great Britain continuously developing and self evaluating, under supervising Maritime Coastguard Agency (MCA) and Maritime Accident Investigation Bureau (MAIB), fulfilling SOLAS Convention, Chapter V Regulation 12, Maritime Safety Committee (MSC) Circular 1065, International Maritime Organization (IMO) Resolution A.857(20) and corresponding with International Association of Marine Aids to Navigation and Lighthouse (IALA) VTS Manual 2008 placing emphasis on IALA Model courses and Training Guidelines.

Despite of every effort was made by the local Hydrographic Department Hull in the scope of survey and dredging, the dynamic and unpredicted siltation of the river due to daily migration of the huge masses of the mud and the other riverbed mate-

rials (mainly on the upper part of the river) is considered as a main reason of the massive ships' groundings, posing highest percentage of overall marine casualties on the River Humber. Grounding incidents divided onto two groups: first when ships were re-floated on the same tide and the second, when ships not re-floated on the same tide (means: re-floated on the next tide or under external assistance). Generally speaking, it is quite obvious that the measured two kinds of groundings showing very similar figures. In presented hereunder results, about 50% of them were caused by wrongly calculated tide values (time and high), or inadequate prediction (tide fluctuation). In 40% of overall cases, the measured accidents were brought out by pilots with 2 years practice or less. Over 25% of total groundings concerned sudden "tide cut" either height or time, in the areas called "no point to return", where was not enough space to turn around the ship and abort the passage¹.

Below diagram illustrates the figures of the total groundings of sea-going ships on the river Humber within the space of five years:

Diagram 1.1 The statistics of the vessels groundings with re-floating



Although every single case of the grounding has been detailed evaluated and analyzed both by MAIB and Humber Estuary Service, at the present stage, it is very difficult to find out about any links between the casualty, the professionalism of the VTS staff, ship's crew negligence and pilot's lack of knowledge. MAIB's grounding investigations revealed that over 50% of all accidents were caused by insufficient under keel clearance and in over 30% cases the official soundings were not covered with actual depths found while grounding or shortly after that.² MAIB strictly recommends to apply by VTS sophisticated and efficient software which allows to assess a require under keel clearance and increase

ruling Under Keel Clearance (UKC) for restricted waters, meeting assumed goals.

Execution of increasing the minimum under keel clearance, in practice is very difficult, because the period of flood tide in the rivers Trent and Ouse is 3 hours only, so high demands would lead to too frequent cancellations of the ships and discontinuation upper river traffic. The most reasonable solutions is applying highly, advanced software, particularly designed for specific waters, conformed with existing systems and flexible collaborated with tide gauges in many locations. Practically such a tool should consist of two independent modules: one for the lower river, second for the upper, therefore UKC requirements are quite different for those two parts of the river. One additional module should be designated for very large ships (VLS), which are subject to completely different UKC and passage criteria. Another additional obstacle making difficult execution for the required UKC, is the fact, that upper river is not covered by radar stations and all monitoring of the traffic is via Automatic Identification Systems (AIS), Radiotelephones (VHF) and Closed-Circuit Television (CCTV). One alternative option could be using the Portable Operation Approaching and Docking Support System (POADSS), by all transiting ships. That conception will be widely presented in the next chapters.

2 ACTUALLY APPLY UNDER KEEL CLEARANCE STANDARDS TO THE RIVER HUMBER

The precise determination of the clear-cut under keel clearance figures still remains as a open issue and the subject to the dispute between safety measures and commercial interests. The relatively huge differences of the surveys in the short intervals is still the main obstacle to work out uniformed UKC figures.

¹ Annual Maritime and Coastguard Agency Report, London 2009

² Harbour Master Humber Annual Report, Hull 2009

Table 2.1 Illustration of the dynamic changes to the depths of the River Ouse (upper Humber) for the period less than one month

| ABP-PORT OF GOOLE | | REACHES DATE: 18/05/09 | | ABP-PORT OF GOOLE | | REACHES DATE: 10/06/09 | |
|--------------------------|----------------|---------------------------|----------------|--------------------------|----------------|---------------------------|----------------|
| CHANNELS | DEPTH (METERS) | CHANNELS | DEPTH (METERS) | CHANNELS | DEPTH (METERS) | CHANNELS | DEPTH (METERS) |
| Goole Reach | 1.90 | Goole Reach | 1.70 | Goole Reach | 1.70 | Goole Reach | 1.70 |
| EAST SIDE TOP | 1.70 | EAST SIDE TOP | 1.60 | EAST SIDE TOP | 1.60 | EAST SIDE TOP | 1.60 |
| EAST SIDE LOWER END | 1.40 | EAST SIDE LOWER END | 1.30 | EAST SIDE LOWER END | 1.30 | EAST SIDE LOWER END | 1.30 |
| WEST SIDE | 1.60 | WEST SIDE | 1.80 | WEST SIDE | 1.80 | WEST SIDE | 1.80 |
| Swinefleet Reach | 1.80 | Swinefleet Reach | 2.20 | Swinefleet Reach | 2.20 | Swinefleet Reach | 2.20 |
| 27a-35 | 1.80 | 27a-35 | 1.10 | 27a-35 | 1.10 | 27a-35 | 1.10 |
| 21 BANK HOUSE | 1.40 | 21 BANK HOUSE | 1.70 | 21 BANK HOUSE | 1.70 | 21 BANK HOUSE | 1.70 |
| LIGHT - LIGHT | 1.90 | LIGHT - LIGHT | 2.70 | LIGHT - LIGHT | 2.70 | LIGHT - LIGHT | 2.70 |
| JETTY - ORCHARD | 2.70 | JETTY - ORCHARD | 1.10 | JETTY - ORCHARD | 1.10 | JETTY - ORCHARD | 1.10 |
| BANK HOUSE | 1.60 | BANK HOUSE | 1.80 | BANK HOUSE | 1.80 | BANK HOUSE | 1.80 |
| HALL STAFFS (SALT MARSH) | 1.60 | HALL STAFFS (SALT MARSH) | 1.10 | HALL STAFFS (SALT MARSH) | 1.10 | HALL STAFFS (SALT MARSH) | 1.10 |
| Yakerfleet Reaches | 1.20 | Yakerfleet Reaches | 1.80 | Yakerfleet Reaches | 1.80 | Yakerfleet Reaches | 1.80 |
| NO 10 PILE TO PILE | 1.20 | NO 10 PILE TO PILE | 1.80 | NO 10 PILE TO PILE | 1.80 | NO 10 PILE TO PILE | 1.80 |
| LIGHT - LIGHT | 1.20 | LIGHT - LIGHT | 1.80 | LIGHT - LIGHT | 1.80 | LIGHT - LIGHT | 1.80 |

Depth of water below the Zero mark at the Tide Gauge Board.
While every care is taken compiling this data from actual soundings, Associated British Ports does not accept responsibility for its accuracy due to the unpredictable stability of the silt on the river bed.

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Hydrographic surveys presented above, for the specific reaches of the river Ouse, in duration of the 23 days show average difference about 0.20 m and in extreme cases even **0.40 and 0.50 m**. The commonly established under keel clearance standards for the rivers Ouse, Trent and upper Humber are 0.20m during the day and 0.30m at night (not excluding ships' Companies higher standards), it means that the difference between fault given depth is almost twice more than actual under keel clearance and directly leads towards potential marine hazard. Another idea to establish higher UKC standard may cause, that required minimum would be (e.g. for value 0.50m) equivalent for a ship with the draught of 5.0m, for lower Humber (UKC is 10% of max. draught). In the cases of less drafted ships, the UKC for upper river would be greater than for lower. Where max. draught for Ouse and Trent is 5.5m in highest spring tide and average draught is 3.80m, such a solution would be absolutely pointless and leads to nowhere. At the present stage it is seeking for the compromise between demanded safe level of navigation and keeping the waterways fully navigable working on the higher standards but that major, essential problem is not still sorted out and it is the subject to further consultations and advanced trials both by Humber Estuary Service and MCA.

3 STATIC METHODS OF THE DETERMINATION UNDER KEEL RESERVE

Generally speaking, the main strategic assumption in the calculating process of estimation a required under keel clearance (UKC) is available water level at the destination referred to the actual ship's draught. Applying this method, consists of the several variations and derivatives but mainly basis on the tide tables for the specific location, date and time upon drew up harmonic curves and math algorithm. Unfortunately mentioned method does not take into consideration changing hydro-met condition affect-

ing desired tide level and leading straight away to apply additional corrections or decisive modifications current passage plan. All factors must be take into the consideration while unexpected conditions are being encountered to complete safe passage of the ship, including sufficient water level when piloting act is aborted (return passage).

3.1 Analytic estimation of the demand height of the tide.

The analytic calculation of the predicted tidal level at the port of destination generally basis on the tide tables worked out for the specific ports and it is the part of preliminary process preparing ship's passage plan. Mentioned method may be recognized as a estimated only, because the all tides given in the tide tables are referred to the High Water for the specific location, not providing the heights for intermediate periods. The manual height interpolation of the tide gives the errors about 7 to 12%, there is 0.35 and 0.5m respectively for the height of the tide 5m, which is unacceptable for 0.3m of the UKC. Besides, relying on the recalculating figures only, given in the Tide Tables without taking into consideration seasonal changes and specifications of the river bed increases the error to the additional 10%, in extremes. Only right, correct action should be applied additional other support or/and alternative reliable methods for double check.

3.2 Using remote gauges for the current tidal valuation

The river Humber is fitted with several tide gauges throughout the navigation traffic routes. The average distance between the gauges is 5-7 Nm, which gives to the navigator current information about tidal condition for the specific location via VTS or internet connection.

The tide prediction is not made of each gauge location (current tide height remotely reading only). Presuming the ship's average speed of 10 knots, bearing mind changing of the datum and assessing variation of the reading for the respective tide gauges the navigator is able to extrapolate the demanded UKC for the specific location, time and height of the tide with necessary margin of the error using following empirical obtained formulas:

$$UKC = [Dr - ((R1 - R2)/2 + dD) + Dth] + 10\% \text{ while sailing upriver on rising tide} \quad (1)$$

$$UKC = [Dr - ((R1 - R2)/2 - dD) + Dth] \text{ while sailing downriver on rising tide} \quad (2)$$

$$UKC = [Dr - ((R1 - R2)/2 - dD) + Dth] + 15\% \text{ while sailing down river on falling tide} \quad (3)$$

where: UKC – under keel clearance [m]

Dr – ship’s draught [m]

R1 – reading from passing tide gauge [m]

R2 – reading from the next nearest tide gauge [m]

dD – difference in the datum between the gauges [m]

Dth – actual depth for specified point below chart datum [m]

For the double check purpose of the UKC may be used the below table, drew up in the over 15 years period basis on statistical observation, referred to the HW Albert Dock and recalculated for the significant location. This table includes all observed seasonal changes of the tide as well as other fluctuations and there is verified and updated annually.

Table 3.1 Height of the tides referred to Albert Dock HW 8.0 metres

| 8.0 metres (HW Albert-Dock) | | | | | | | | | | | |
|-----------------------------|------|------|------|------|-----|-----|-----|------|------|------|-----|
| | 5hrs | 4hrs | 3hrs | 2hrs | 1hr | HW | 1hr | 2hrs | 3hrs | 4hrs | 5h |
| Spurn Point | 2.4 | 3.6 | 4.9 | 6.0 | 6.4 | 6.3 | 5.6 | 4.4 | 3.1 | 2.2 | 1.1 |
| Immingham | 2.2 | 3.4 | 4.7 | 5.9 | 6.7 | 6.7 | 6.1 | 5.0 | 3.7 | 2.6 | 1.1 |
| Albert Dock | 1.6 | 2.7 | 4.0 | 5.3 | 6.3 | 6.8 | 6.3 | 5.3 | 4.1 | 2.9 | 2.1 |
| Humber Bridge | 1.6 | 2.4 | 3.4 | 4.6 | 5.7 | 6.2 | 6.0 | 5.0 | 4.0 | 3.0 | 2.1 |
| Brough | 1.1 | 1.3 | 2.1 | 3.6 | 4.8 | 5.6 | 5.5 | 4.6 | 3.5 | 2.6 | 1.1 |
| WW Dykes | 1.0 | 1.0 | 1.6 | 3.0 | 4.5 | 5.3 | 5.4 | 4.4 | 3.5 | 2.6 | 2.1 |
| Blacktoft | 0.4 | 0.1 | 0.7 | 2.2 | 3.7 | 4.6 | 4.8 | 3.9 | 2.9 | 2.1 | 1.1 |
| Goole Docks | 1.0 | 0.8 | 0.7 | 1.3 | 2.8 | 4.3 | 4.8 | 4.2 | 3.3 | 2.5 | 2.1 |
| Burton Stather | 0.0 | 0.0 | 0.3 | 1.7 | 3.1 | 4.2 | 4.4 | 3.6 | 2.7 | 1.8 | 1.1 |
| Flixborough | 0.3 | 0.0 | 0.0 | 1.4 | 2.6 | 4.0 | 4.4 | 3.6 | 2.6 | 1.8 | 1.1 |
| Grove | 0.2 | 0.0 | 0.0 | 0.7 | 2.0 | 3.5 | 4.1 | 3.4 | 2.5 | 1.8 | 1.1 |
| Keadby | 0.0 | 0.0 | 0.0 | 0.3 | 2.3 | 3.3 | 3.8 | 3.3 | 2.4 | 1.6 | 1.1 |

3.3 Comparing the tide fluctuation to the secondary location

Seeking of the secondary ports, with similar characteristic of the sea/river bed, the datum and not far away located from defined area where is more likely any fluctuation tide data may be used for the extrapolating tidal condition on the site in our interests.

There are several basic assumptions should be made:

- the occurrence of the High Water must be not earlier than 3 hours and later than 7,
- no significant seasonal changes should be affecting the observations,
- mutual changes with the datum not exceeding 1 meter,
- the secondary location has to be situated in the north of defined area,

The North Shields was chosen as a secondary location for the River Humber upon the years of careful observations and wide-ranging analysis. So far there is not any math algorithm allowing precisely described mutual correlation between such a huge main and secondary locations. The average accuracy applying above method are vary and oscillating between 65 and 72%.

4 DYNAMIC EVALUATION OF THE AVAILABLE UNDER KEEL CLEARANCE

Dynamic changes of the shipping conditions, such as tidal stream sets and rates, weather conditions, available depths, ships’ traffic density or common technical difficulties with the service of the locks or berths, leading towards arising the potential threats and near miss situations for shipping safety in relation to the execution of the original passage plans. VTS operators make every efforts to update any essential data, affecting shipping, either currently or at the periodical broadcasts, but it contents only major information and not included any minor and dynamic developing potential endangers for the specific area. All navigators

(pilots, masters, pilot exemption certificate (PEC) holders) should have the access to any online nautical, hydro-meteorological, bathymetric and traffic information, covering their passage areas. Such possibilities offers newly working out into the practice, Portable Operational and Docking Support System, commonly known as POADSS.

4.1 Usage of the Portable Operational and Docking Support System (POADSS).

The POADSS project successfully culminated in live demonstration in Lisbon, last October 2008 proving its complete suitability³.

The POADSS unit consists of three main elements, two onboard units and the shore one. One onboard unit is an Instrument Unit and the other is a laptop displaying all relevant information for receiving and transmitting data to and from the shore based unit by means of mobile broadband. That information exchange ashore by POADSS Ground Server Station, which sources data from VTS, tide gauges and AIS transmitters. Such own stored data gives to the navigator overview ship’s static and dynamic information details as well as surrounding traffic image and environmental conditions in comprehensive overview of all necessary parameters of the particular ship on her passage. Distinct from mostly applied pilotage units the POADSS monitors vertical position (3D) and all dynamic motions. There are four main new applications:

- Internal Measurement Unit with Global Navigation Satellite System (GNSS) for determination all dynamic ship’s movement,
- Wireless broadband to exchange information in real time (Web or local map service).

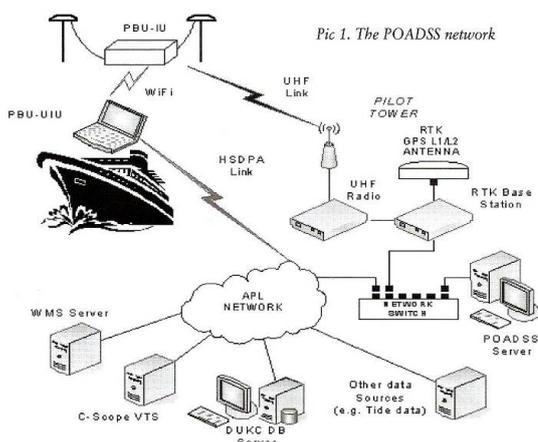
³ The Pilot No.296, United Kingdom Maritime Pilot’s Association, January 2009

- Dynamic high density bathymetric and survey data displayed on electronic chart including true dynamic safety contour.
- Dynamic Under Keel Clearance (DUKC®) software.

The above mentioned applications efficiently reduce voice radio communications and maximizes the usability of fairway and enhances the efficiency of the traffic flow. Interoperability with VTS centre is a key element and by using Web Map Service the overall VTS traffic image can be overlaid on the POADSS Electronic Navigation Chart. If the broadband connection lost then AIS information remains available by pilot's plug connection.

However benefits of usage the POADSS are obvious some restrictions and inconveniences still exist:

- if specialized docking system is deployed, this might take up to 15 minutes to set up it,
- still some vessels, such barges or yachts are not fitted with AIS causing POADSS not effective as expected,
- not approved operating and training standards,
- by using the POADSS in conjunction with Dynamic Passage Planning DPP the maximum draft could be considerably increased and the tidal windows widened without compromising the safety or efficiency of other traffic,
- development of Fibre Optic Gyro's and Micro Electronic Motion Sensors MEMS
- presently are not advanced enough and not offer sufficient accuracy and reliability. It is expected to reach those goal in the next five years.
- the coverage of wireless broadband is still unsatisfactory.
- present stage of development of E-Navigation is not fully capable to be integrated with all POADSS applications.
- The usage of the POADSS is pretty limited at its functions in very narrow river channels and restricted fairways (upper Humber, rivers Ouse and Trent for instance).



Pic 1. The POADSS network

5 METEOROLOGICAL EFFECTS ON TIDES

All meteorological conditions more or less change the tide figures, next affecting available depth at the port of destination closely linked with under keel clearance on the ship's passage. Meteorological condition which differ from the average will cause corresponding differences between predicted and actual tide. Some of the effects are discussed below.

5.1 The effect of the wind

There was observed that winds blowing longer than 24 hours with the force above 7B from the north directions causing drop of the tide about 30-40cm, paradoxically strong southerly winds don not affecting significantly the height of the tide. After long wind blowing periods (probability more than 50%) there is more likely that the tide will be above prediction in proportion to the windy period. The new algorithm about wind effect to the tide for river Humber is under the progress by the Author of hereby Paper .

5.2 Barometric pressure

The tide tables are computed for average barometric pressure, any significant changes in the atmospheric pressure immediately are reflected in the tidal data. A difference from the average of 34 hPa can cause a difference in height of about 0.3m. That aspect is frequently passed over but is still so essential for navigation on the margin UKC. During predominant of low pressure, for the stationary low, the increase in elevation can be found by the formula⁴:

$$R = [0.01(1010-P)] \times 0.3; [m]$$

R – increase in elevation [m]

P – actual atmospheric pressure [hPa]

For the moving low, the increase in elevation is given by the formula:

$$R1 = \{R / [1 - (C / gh)]\} \times 0.3 [m]$$

C – rate of low motion [m/s]

g – acceleration to the gravity [32.2 m/s]

h – depth of the water [m]

The number of the British VTS are equipped with modern software applying changes in barometric

⁴ N.Bowditch, The American Practical Navigator, National

Imagery and Mapping Agency L., Publication No.9, 2002

pressure for tide predictions. So, far VTS Humber is not fitted with such a software.

5.3 *Icing*

The rivers Ouse and Trent were frozen since 1962. During 2 months period relatively thick ice on the both rivers made difficulties with the shipping as well as seriously affected the tidal conditions. In the extreme cases the congested ice caused decreasing the height of the tide to figure of 60cm.

5.4 *The Aegir*

The “Aegir” is the local word means the head of the significant tidal wave breaking through the river bars and creeks. The aegir occurs while high spring tides around the time of high water (about half an hour before). That phenomena seriously interferes predicted height of the tide causing numerous eddies, top runs and significantly gaining tidal streams. Early indication and proper monitoring of the aegir allow to avoid unnecessary risks to navigation. Unfortunately, only visual observations and usage of probability methods can made at the present stage. Gathering all information can allow in future to develop more effective statistical methods.

6 SUMMARY

The huge numbers of groundings as a result of insufficient under keel clearance are still at unacceptable high level for last several years. Every effort should made to seek out a reasonable compromise between securing minimum under keel clearance requirements for keeping the waterways navigable and rigid standards to the ships’ safety. There is no doubt that disturbing statistics should prompt for implementation of the new solutions and different approach the subject of the minimum safe UKC taking into consideration that the human factor still plays major role. The matter of semi liquid sea/river bed being the pattern of any measures and surveys remains still open shall be without any delay sorted out by relevant authorities as well as by the local Safety Navigation River Committees (SNRC).

So far there is no one defined universal formula for UKC determination for the such extensive area as Humber estuary in the wide space of time. Presently, the main existing “tool” is the probabilistic method, commonly known as dynamic prediction using with co-relation with specialized software. The optimistic prospects after series of advanced trials are placed in the POADSS. At the present stage, the other methods as a deterministic or a stochastic can be used as a support utilities only.

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