#HashEx
BLOCKCHAIN SECURITY

Crystl Vaults

smart contracts final audit report

May 2022

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Contents

1. Disclaimer

This is a limited report on our findings based on our analysis, in accordance with good industry practice at the date of this report, in relation to cybersecurity vulnerabilities and issues in the framework and algorithms based on smart contracts, the details of which are set out in this report. In order to get a full view of our analysis, it is crucial for you to read the full report. While we have done our best in conducting our analysis and producing this report, it is important to note that you should not rely on this report and cannot claim against us on the basis of what it says or doesn't say, or how we produced it, and it is important for you to conduct your own independent investigations before making any decisions. We go into more detail on this in the disclaimer below – please make sure to read it in full.

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2. Overview

HashEx was commissioned by the Crystl Finance team to perform an audit of their smart contracts. The audit was conducted between 2022-01-18 and 2022-01-28.

The purpose of this audit was to achieve the following:

- Identify potential security issues with smart contracts
- Formally check the logic behind given smart contracts.

Information in this report should be used for understanding the risk exposure of smart contracts, and as a guide to improving the security posture of smart contracts by remediating the issues that were identified.

The code is available at @polycrystal/polycrystal-vaults GitHub repository after 426d351 commit. The updated code was rechecked in the ca3db5d commit.

Audited contracts have been deployed to the Polygon mainnet:

VaultHealer 0xe5B5da7B82A3057b21c2B0dCef34c25EAA45FE4f

VaultHealerDeploy 0x19E010Ca74E4f6082f005cE2C0c7EB11af30E633

VaultHealerAuth 0xB12Ef4742163735ebc2D670039997563cf8B2A8F

VaultHealerFeeManager 0xec9438eC81Cde8b1D2DEF9da21AcB4900AEf8b69

BoostPool implementation 0xA50B6B367C3240dC40427d271f7d8BFBcabf2346

Strategy implementation 0x4EAA514fb024c35aa169Cfd0ba4D936578e9A63B

StrategyQuick implementation 0xA827F56a439025345a2940BD7Aef90b0FAf75BA5

QuartzUniV2Zap 0x6eAe78BB3DB6d556762a7823CF0A922064aefE0c

2.1 Summary

Project name	Crystl Vaults
URL	https://www.crystl.finance
Platform	Polygon Network
Language	Solidity

2.2 Contracts

Name	Address
ContractSizer	
BaseStrategySwapLogic	
VaultHealerBase	
VaultHealerEarn	
VaultHealerGate	
Magnetite	
VaultFeeManager	0xec9438eC81Cde8b1D2DEF9da21AcB4900AEf8b69
Fee	
BaseStrategyVaultHealer	
VaultHealerFactory	
BoostPool	0xA50B6B367C3240dC40427d271f7d8BFBcabf2346
BaseStrategy	

TacticMasterHealerWithReferral	
Cavendish	
VHStrategyProxy	
VaultHealer	0xe5B5da7B82A3057b21c2B0dCef34c25EAA45FE4f
Strategy/StrategyVHStandard	0x4EAA514fb024c35aa169Cfd0ba4D936578e9A63B
TacticMasterHealer	
StrategyConfig	
VaultHealerBoostedPools	
QuartzUniV2Zap	0x6eAe78BB3DB6d556762a7823CF0A922064aefE0c
PrismLibrary	
VaultView	
Tactics	
TacticMiniApe	
LibQuartz	
StrategyQuick	0xA827F56a439025345a2940BD7Aef90b0FAf75BA5
VaultHealerAuth	0xB12Ef4742163735ebc2D670039997563cf8B2A8F
PRBMath	
VaultHealerDeploy	0x19E010Ca74E4f6082f005cE2C0c7EB11af30E633
VaultChonk	
Multiple contracts	

3. Found issues

High	2 (8%)
Medium	4 (16%)
Low	7 (28%)
Info	12 (48%)

C1. ContractSizer

ID	Severity	Title	Status
C1-01	Info	extcodesize may return 0 for a contract	Resolved

C2. BaseStrategySwapLogic

ID	Severity	Title	Status
C2-01	Medium	Wrong slippage and deadline usage	Acknowledged
C2-02	Low	Same dust parameter for tokens with different decimals	Resolved
C2-03	Low	External calls may spend gas	Resolved
C2-04	Info	Redundant code	Resolved
C2-05	Info	Inconsistent comment	Resolved
C2-06	Info	Code style	Resolved

C3. VaultHealerBase

ID	Severity	Title	Status
C3-01	Low	Redundant code	Partially fixed
C3-02	Info	Lack of events	Resolved
C3-03	Info	No revert message	Resolved

C4. VaultHealerEarn

ID	Severity	Title	Status
C4-01	Low	Gas optimization	Resolved

C5. VaultHealerGate

ID	Severity	Title	Status
C5-01	High	accRewardTokensPerShare monotonic growth	Resolved
C5-02	Medium	lastEarnBlock is not updated	Resolved
C5-03	Low	Division error	Resolved
C5-04	Info	Code style	Resolved

C6. Magnetite

ID	Severity	Title	Status
C6-01	Medium	Constant return	Resolved
C6-02	Low	Can't be called externally	Resolved
C6-03	Info	Sub-paths can only be updated manually	Resolved

C7. VaultFeeManager

ID	Severity	Title	Status
C7-01	High	Exaggerated owner rights	Resolved
C7-02	Low	Gas optimization	Resolved

C8. Fee

ID	Severity	Title	Status
C8-01	Info	Total fees may reach 100%	Resolved

C9. BaseStrategyVaultHealer

ID	Severity	Title	Status
C9-01	Info	Code style	Resolved

C10. VaultHealerFactory

ID	Severity	Title	Status
C10-01	Info	Code style	Resolved

C11. BoostPool

ID	Severity	Title	Status
C11-01	Medium	Logic violation	Resolved

C32. Multiple contracts

ID	Severity	Title	Status
C32-01	Info	Pragma and Solidity version discrepancy	Acknowledged

4. Contracts

C1. ContractSizer

Overview

The contract consist of only one function `sizeOf()`, that returns the passed contract's code size.

Issues

C1-01 extcodesize may return 0 for a contract

Info Resolved

The size check can be bypassed [1].

Team response

No action needed, the contract was only created for ad hoc use.

C2. BaseStrategySwapLogic

Overview

The abstract contract and the part of the StrategyVHStandard contract inheritance scheme.

Issues

C2-01 Wrong slippage and deadline usage

Medium Acknowledged

Calculating the slippage and setting a deadline with `block.timestamp` inside the `safeSwap()` function does not affect the transaction's success. These parameters should be obtained off-chain. Calculating the slippage as a percentage of `router.getAmountsOut()` affects only the transfers of tokens with fees on transfers.

This issue was moved to the BaseStrategy contract in the code update.

Team response

We're happy that the risk is not substantial given that we only swap on earn, and are not at a size where front-running would be that profitable for anyone. Setting params offchain too much of a lift right now. Might look at using Uniswap priceCumulativeLast solution at some point in the future.

C2-02 Same dust parameter for tokens with different decimals

Low Resolved

The value of a token may differ according to the `totalSupply` and `decimals` value. Fixing the significance threshold is incorrect as the same amount of different tokens can be valued differently.

Team response

Our plan here is to create separate dust variables for each token - we will reduce these to one byte variables to save on storage space

C2-03 External calls may spend gas

Low Resolved

Transfers of native currency with `receiver.call{value}` in L111 may cause significant gas spending if the receiver implements the fallback function. This can be avoided by fixing the call gas to a constant or variable amount.

C2-04 Redundant code

Info Resolved

L34 is unnecessary and could be removed.

C2-05 Inconsistent comment

Info Resolved

The correctness of the `for()` loop execution depends on the last element in the `earned` array. If it's not zero-initialized, a transaction would fail due to an indexation error, whereas the problem is in the last array element value.

C2-06 Code style

Info Resolved

TODO & testing comments in L59, 82, 123, 126, 132, 134-147, 152, 160, 164, 170, 174..

C3. VaultHealerBase

Overview

The abstract contract, the part of the VaultHealer contract inheritance scheme.

Issues

C3-01 Redundant code

Low Partially fixed

a. The `findVid()` function has internal visibility but is never used;

b. The first line check in `whenNotPaused()` function becomes unnecessary after the update.

```
if (!vaultInfo[vid].active) revert PausedError(vid);
```

It duplicates the constraint in `paused()` function.

```
function paused(uint vid) public view returns (bool) {
    return !vaultInfo[vid].active || ((vid >> 16) > 0 && paused(vid >> 16));
}
```

C3-02 Lack of events

Info Resolved

When `vaultFeeManager` is changed no event is emitted.

C3-03 No revert message

Info Resolved

L92 requirement checks the vault id for inequality to zero. The opposite means that the passed strategy address is invalid. If the requirement is not met, the transaction is reverted with an empty message.

C4. VaultHealerEarn

Overview

The abstract contract, the part of the VaultHealer contract inheritance scheme.

Issues

C4-01 Gas optimization

Low Resolved

a. Unchecked math may save gas in L110, L114.

b. Excessive reads from storage in L103, L105.

C5. VaultHealerGate

Overview

The abstract contract, the part of the VaultHealer contract inheritance scheme. It realizes `deposit()` and `withdraw()` functions through which users will interact with the VaultHealer.

Issues

C5-01 accRewardTokensPerShare monotonic growth

High Resolved

The `accRewardTokensPerShare` variable stores the number of target tokens that may be received for the current strategy token. `accRewardTokensPerShare` is recalculated each time during deposit and withdrawal operation with vaults that have `targetVid`. In the `UpdatePoolAndRewarddebtOnDeposit()` and `UpdatePoolAndWithdrawCrystlOnWithdrawal()` functions updated variable is received by price accumulation, this results in a constant `accRewardTokensPerShare` growth. In other words, the token per token ratio only increases what breaks vaults' tokenomics and makes deposited tokens not fully backed by the declared target tokens amount. Token per token ratio accumulation may lead to flashloan attacks and users' assets loss.

Recommendation

Without the documentation, we can't validate the `accRewardTokensPerShare` logic. We recommend adding unit tests for the strategies with non-zero `targetVid`.

C5-02 lastEarnBlock is not updated

Medium Resolved

`lastEarnBlock` field in `VaultInfo` structure is used in earn functions to ensure a vault is processed only once in a block. However, the field is updated neither in Strategy nor in VaultHealer methods. Thus, the vault may be earned multiple times in the block. The issue was detected in the update commit.

Recommendation

Consider update the variable after a successful call or remove the corresponding checks.

C5-03 Division error

Low Resolved

There are possible division errors while `targetVidShares` calculation in `withdrawTargetTokenAndUpdateOffsetsOnWithdrawal()` function.

```
_vidSharesRemoved * (totalSupply(targetVid) + totalOffset) / totalSupply(_vid)
- fromOffset * _vidSharesRemoved / balanceOf(_from, _vid)
```

If `totalSupply(_vid)` or `balanceOf(_from, _vid)` is much larger than its numerator, one of the multipliers will be nullified and will lead to further `targetVidShares` miscalculation. This may cause withdrawal errors and users' funds loss. The issue was detected in the update commit.

Recommendation

Consider reducing fractions to a single one:

```
uint256 totalSupply_vid = totalSupply(_vid);
uint256 balanceOf_from_vid = balanceOf(_from, _vid);

( _vidSharesRemoved * (totalSupply(targetVid) + totalOffset) * balanceOf_from_vid
- fromOffset * _vidSharesRemoved * totalSupply_vid )
/ balanceOf_from_vid / totalSupply_vid
```

Take note that this approach may cause an overflow of numerator.

C5-04 Code style

Info Resolved

TODO & testing comments in L32, 33, 35, 144, 154, 174, 176, 186, 200.

C6. Magnetite

Overview

The contract generates and stores swaps paths.

Issues

C6-01 Constant return

Medium Resolved

`pathAuth()` always returns true making the `findAndSavePath()` function accessible for anyone.

Team response

We have reinstated the check within pathAuth(), and it is working fine again now (it was only removed originally for debugging, and our mistake not to reinstate it)

C6-02 Can't be called externally

Low Resolved

The `setAutoPath_()` function has external visibility, but the L45 requirement allows calls only to `address(this)` contract. Thus, the function can only be called internally then visibility should be changed or access to the function should be reconsidered.

C6-03 Sub-paths can only be updated manually

Info Resolved

During sub-path generation in `_setPath()`, intermediate paths that can be updated only manually with `overridePath()` are created.

C7. VaultFeeManager

Overview

The contract manages fee percents and fee receivers.

Issues

C7-01 Exaggerated owner rights

High Resolved

The owner is able to increase the earn and withdrawal fees up to 100% anytime. In this case, users' funds may be considered locked, since if they attempt to withdraw their deposits, they would be totally transferred to the owner.

Recommendation

The `FEE_SETTER` role must belong to a Timelock contract with a minimum delay of at least 24 hours. This won't stop the admin from possible tax shifts but will help users to be informed about upcoming changes. They will be able to make a decision in advance before the fee increases.

Team response

We have put in a limit of 30% on the earn fee. We considered the timelock option, but in the end decided that because the fee is only on earn (not a withdrawal fee on principal, for example) that we're ok with this not being in a timelock.

C7-02 Gas optimization

Low Resolved

`FEE_MAX` is declared but not used.

C8. Fee

Overview

Library defining `Fee` datatype.

Issues

C8-01 Total fees may reach 100%

Info Resolved

The project taxes earns from masterchefs pools and all withdrawal operations. Each of these taxes can be up to 100%, resulting in the owner getting all masterchef rewards and all user's funds if one wants to withdraw deposits.

C9. BaseStrategyVaultHealer

Overview

The abstract contract, the part of the StrategyVHStandard contract inheritance scheme.

Issues

C9-01 Code style

Info Resolved

TODO & testing comments in L13, 14, 15, 36, 37.

C10. VaultHealerFactory

Overview

The abstract contract, the part of the VaultHealer contract inheritance scheme. The contract includes gas-efficient functionality for adding new vaults using a proxy pattern.

Issues

C10-01 Code style

Info Resolved

TODO & testing comments in L9, 28, 30-41.

C11. BoostPool

Overview

Contract for additional rewards distribution to be operated via VaultHealer.

Issues

C11-01 Logic violation

Medium Resolved

When a new `bonusEndBlock` is set in the `setBonusEndBlock()` function, `rewardTotalSupply` and/or `rewardPerBlock` should be updated. Otherwise, pool rewards may exceed `totalSupply` of `rewardToken`.

C12. BaseStrategy

Overview

The abstract contract, the part of the StrategyVHStandard contract inheritance scheme. No issues were found.

C13. TacticMasterHealerWithReferral

Overview

The auxiliary contract for interacting with MasterChef-like contracts via DELEGATECALL. No issues were found.

C14. Cavendish

Overview

The library for strategy proxy deployment. Was added in the update. No issues were found.

C15. VHStrategyProxy

Overview

The proxy for StrategyVHStandard. Created architecture is gas-efficient solution for deployment of strategy contracts. The proxy also has rights delimitation and provides only view access to strategy's methods if caller is not VaultHealer. No issues were found.

C16. VaultHealer

Overview

Main contract in the VaultHealer scheme. After the update the contract overrides isApprovedForAll() function approving all deposit proof NFTs for trustedForwarder. This means, trustedForwarder is able to transfer users' NFTs to himself and withdraw their deposits. No issues were found.

C17. Strategy/StrategyVHStandard

Overview

Main strategy contract, was renamed in the update. No issues were found.

C18. TacticMasterHealer

Overview

Auxiliary contract for interacting with MasterChef-like contracts via DELEGATECALL. No issues were found.

C19. StrategyConfig

Overview

The library helps to extract information from Tactics data structures. Was added in the update. No issues were found.

C20. VaultHealerBoostedPools

Overview

The abstract contract, the part of the VaultHealer contract inheritance scheme. It allows the owner or anyone with `BOOST_ADMIN` role to manage the boosting pools. No issues were found.

C21. QuartzUniV2Zap

Overview

The contract helps with the swap operation of vaults tokens. No issues were found.

C22. PrismLibrary

Overview

A generic UniswapV2 library. Was added in the update. No issues were found.

C23. VaultView

Overview

Support contract for VaultHealer. Contains view functions of the VaultHealer to reduce the size of its deployed bytecode. No issues were found.

C24. Tactics

Overview

The library helps Tactics to interact with masterchefs. Was added in the update. No issues were found.

C25. TacticMiniApe

Overview

Auxiliary contract for interacting with MasterChef-like contracts via DELEGATECALL. No issues were found.

C26. LibQuartz

Overview

The library with auxiliary swap functions. Was added in the update. No issues were found.

C27. StrategyQuick

Overview

Strtegy extension for the QuickSwap's DragonLair. Was introduced with the update. No issues were found.

C28. VaultHealerAuth

Overview

Authentication contract for VaultHealer, based on the AccessControlEnumerable model from OpenZeppelin library. Was introduced with the update. No issues were found.

C29. PRBMath

Overview

Fixed-point math library. Was introduced with the update. No issues were found.

C30. VaultHealerDeploy

Overview

Deployment helper and config keeper contract for VaultHealer. Was introduced with the update. No issues were found.

C31. VaultChonk

Overview

Library contract for VaultHealer that contains vault management logic. Was introduced with the update. No issues were found.

C32. Multiple contracts

Overview

The issues are related to multiple contracts.

Issues

C32-01 Pragma and Solidity version discrepancy

Info Acknowledged

The declared pragma conditions are partially incompatible with the used version of Solidity. Some contracts using `0.8.13` Solidity release features such as `memory-safe` annotation and `global` namespacing have a pragma acceptance range `^0.8.9`. Whereas an attempt to compile these contracts with a compiler version earlier than `0.8.13` would cause an error. The problem is relevant for `Cavendish`, `StrategyConfig`, `Tactics`, `VaultChonk`.

5. Conclusion

2 high severity issues were found during the audit and fixed in the update afterwards. The reviewed contracts are highly dependent on the owner's account. The contracts are upgradeable and their implementation can be switched by the owner.

Appendix A. Issues severity classification

- **Critical.** Issues that may cause an unlimited loss of funds or entirely break the contract workflow. Malicious code (including malicious modification of libraries) is also treated as a critical severity issue. These issues must be fixed before deployments or fixed in already running projects as soon as possible.
- **High.** Issues that may lead to a limited loss of funds, break interaction with users, or other contracts under specific conditions. Also, issues in a smart contract, that allow a privileged account the ability to steal or block other users' funds.
- **Medium.** Issues that do not lead to a loss of funds directly, but break the contract logic. May lead to failures in contracts operation.
- **Low.** Issues that are of a non-optimal code character, for instance, gas optimization tips, unused variables, errors in messages.
- **Info.** Issues that do not impact the contract operation. Usually, info severity issues are related to code best practices, e.g. style guide.

Appendix B. List of examined issue types

- Business logic overview
- Functionality checks
- Following best practices
- Access control and authorization
- Reentrancy attacks
- Front-run attacks
- DoS with (unexpected) revert
- DoS with block gas limit
- Transaction-ordering dependence
- ERC/BEP and other standards violation
- Unchecked math
- Implicit visibility levels
- Excessive gas usage
- Timestamp dependence
- Forcibly sending ether to a contract
- Weak sources of randomness
- Shadowing state variables
- Usage of deprecated code

Appendix C. References

1. Bypass Contract Size Check. URL: https://solidity-by-example.org/hacks/contract-size.

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